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# A comparative analysis of U. S. Army Air Defense Artillery strategies using the Joint Theater Level Simulation model

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# THESIS

A COMPARATIVE ANALYSIS OF U.S. ARMY AIR DEFENSE ARTILLERY STRATEGIES USING THE JOINT THEATER LEVEL SIMULATION MODEL

by

David M. Savage

September, 1990

Thesis Advisor: Samuel H. Parry

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2. Balanced Concentration (point defense)
3. Rear Area Concentration (point defense)

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# A Comparative Analysis of U. S. Army Air Defense Artillery Strategies Using the Joint Theater Level Simulation Model

by

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Submitted in partial fulfillment of the
requirements for the degree of

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from the

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# ABSTRACT

This thesis seeks to determine if US Army Air Defense Artillery (ADA) units positioned in a belt defense perform better than the point defense that the US Army currently uses. It does this through a comparison of three ADA defense strategies:

1. Forward Concentration (belt defense)
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# I. PROBLEM DESCRIPTION

## A. BACKGROUND

The mission of the United States Army Air Defense Artillery (ADA) is:

> To nullify or reduce the effectiveness of attack or surveillance by hostile aircraft or missiles after they are airborne .... [Ref. 1: p. 1-1]

or, more succinctly, to shoot down enemy airplanes.

Where should ground-based ADA units be positioned to best accomplish this mission? The US Army has answered this question by placing ADA units under the command of brigade and larger-sized combat units. The combat unit commander designates and prioritizes specific assets to be protected and the ADA units are positioned to protect the assets [Ref. 2: p. 52]. In this type of ADA defense, called point defense [Ref. 1: p. 4-5], there are often not enough ADA units to adequately protect all the assets a commander desires. An enemy aircraft could be flying around in his opponents rear area and, as long as it avoids those assets that are protected, it could escape being fired upon.[1]

In contrast to the characteristics of a point defense, a belt defense utilizes ADA units in a "... linear configuration to provide early attrition of the enemy as he attempts penetration to rear areas." [Ref. 1: p. 4-5] A belt defense is much like an invisible wall on the battlefield, and any aggressor who attempts to pass through the wall will be fired upon. Although a belt defense is impractical, indeed undefined for battalion, brigade, and division-sized fronts, it can be used for corps and larger size fronts. Belt defenses are criticized because they use a large amount of ADA resources and few commanders want an ADA unit protecting an open gap containing no assets when it could be providing increased coverage to one of their high-priority assets. Also, some belt defenses can be defeated by flying around either end [Ref. 1: p. 4-5].

If a belt defense were constructed in such a way that these criticisms were invalid, would it provide a better defense than the point defense currently in use? This thesis seeks to answer this question in the limited context of a conventional war in Central Europe against Soviet forces.

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[1] This presupposes that the opponent's air force does not send an interceptor up after it.

## B. FORMULATION OF PROBLEM

### 1. Means of Comparing Strategies

In order to compare strategies, such as what type of ADA defense to use, a means of comparison must be established. The ultimate means of comparison to use for this problem is to analyze the data from a real war, or several wars. Unless there exists an historical record of wars which includes data upon which a comparison can be made, the use of real war as a means of comparing strategies is infeasible. Another means of comparison is through the use of a military exercise. This method is appealing because numerous variables that might otherwise affect the results can be held constant.

A different means of comparing strategies, and the one that will be used in this thesis, is to use a computer model to simulate war. There are several advantages gained by using a computer model as a means of comparing strategies:

- A great degree of control can be obtained using a computer model; it allows the researcher to isolate variables of interest.
- It allows the analyst control over the amount and type of data to be collected.
- Using a computer model allows verification of results, due to the ability to replicate the model.
- Lastly, and perhaps the most important, is the ability for one person to use a computer model to simulate dozens of wars in a short amount of time for relatively little expense.

It is for these reasons that the means of comparison for ADA defense strategies in this thesis is a computer model of war.

### 2. Choosing a War

What war should be simulated on the computer? The answer to this question should be based primarily on the ADA strategies to be compared. First, the war should not be a contrived, fictitious, 'sterile' war; it should be fought in a specific, reasonable location against an identified foe. The feasibility and realness of a computer simulated war gives a measure of credence and validity to the results that cannot be obtained by a contrived war. Second, the war needs to be one in which each type of ADA defense strategy could be feasibly used. It would make little sense to compare point defense to belt defense in a war in which no commander would even consider using a belt defense. One war scenario which meets the above prerequisites is the Fulda Gap scenario.

The Fulda Gap is a 70 kilometer wide salient that lies along the border contiguous to E. Germany and W. Germany near the W. German town of Fulda (see Figure 1 on page 3). This gap has historically been the route of choice for invasion into

Germany and France, and it might well be the choice of Warsaw Pact forces [Ref. 3: p. 124]. The modern Fulda Gap scenario is a well-known scenario among military modelers. It pits US (or NATO) forces against Soviet (or Warsaw Pact) forces in the Fulda Gap. This scenario is excellent for purposes of comparing ADA strategies. The Soviet Union possesses a large number of advanced fighter and bomber aircraft and is perhaps our most formidable foe. An air attack from Soviet forces would be a genuine test of US Army ADA strategies.

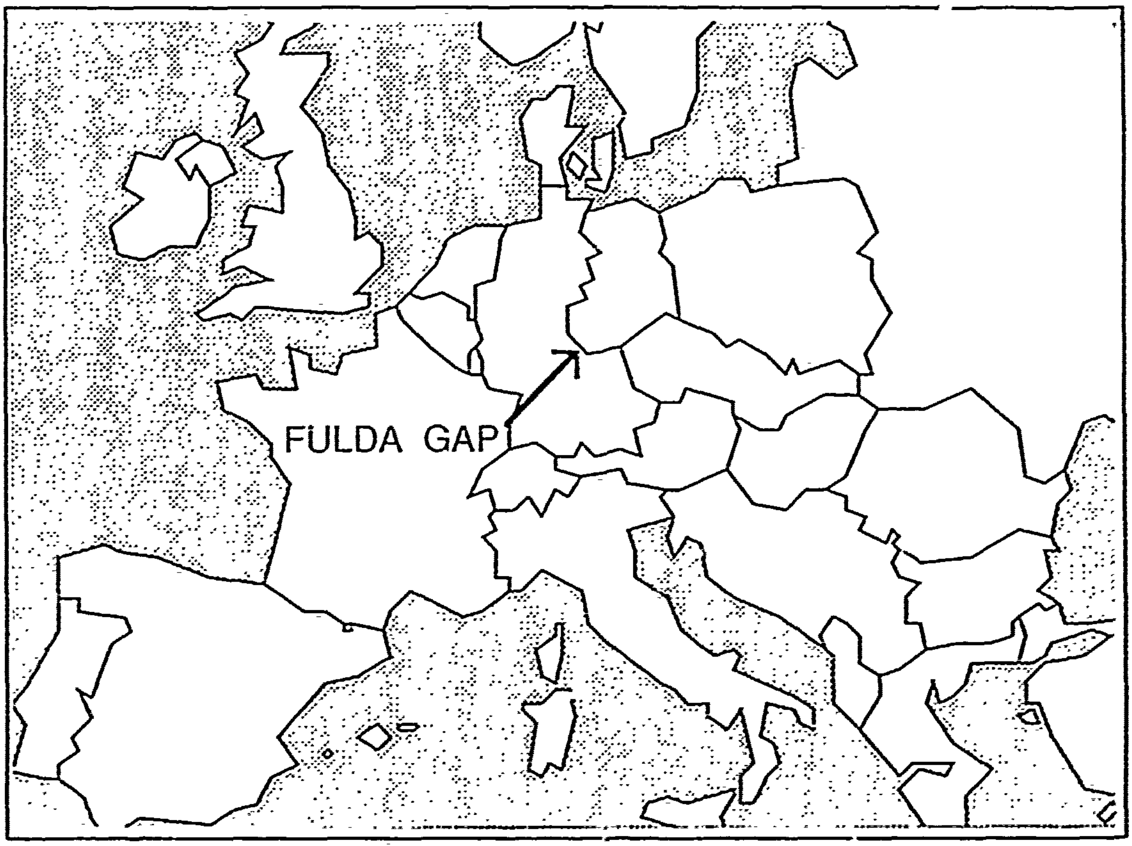



Figure 1. Map of Europe showing location of Fulda Gap

In light of recent events concerning the reunification of Germany, it could be argued that the Fulda Gap scenario is no longer a valid option for potential conflict. The following responses are offered:

1. Notwithstanding the reunification of Germany, history has shown the Fulda Gap to be a likely route of invasion, independent of whether the government controlling it was friendly or belligerent.
2. It is not wise to throw away war plans or discount possible scenarios after over three decades of a military standoff due to the events of one or two years.

3. For comparing ADA strategies, the actual location of the war or the name of the opponent is not as important as the number and type of aircraft that are attacking. The actual business of air defense, after all, takes place several thousand feet above the ground.

3. **Structure of Problem**

The thesis problem of comparing ADA strategies is structured as a comparison of three different defenses: balanced, forward concentration, and rear area concentration.

*a. Balanced Defense*

The balanced defense is the name given to the air defense strategy that the US Army currently uses (discussed on page 1). Figure 2 depicts a simplified version of the balanced defense.

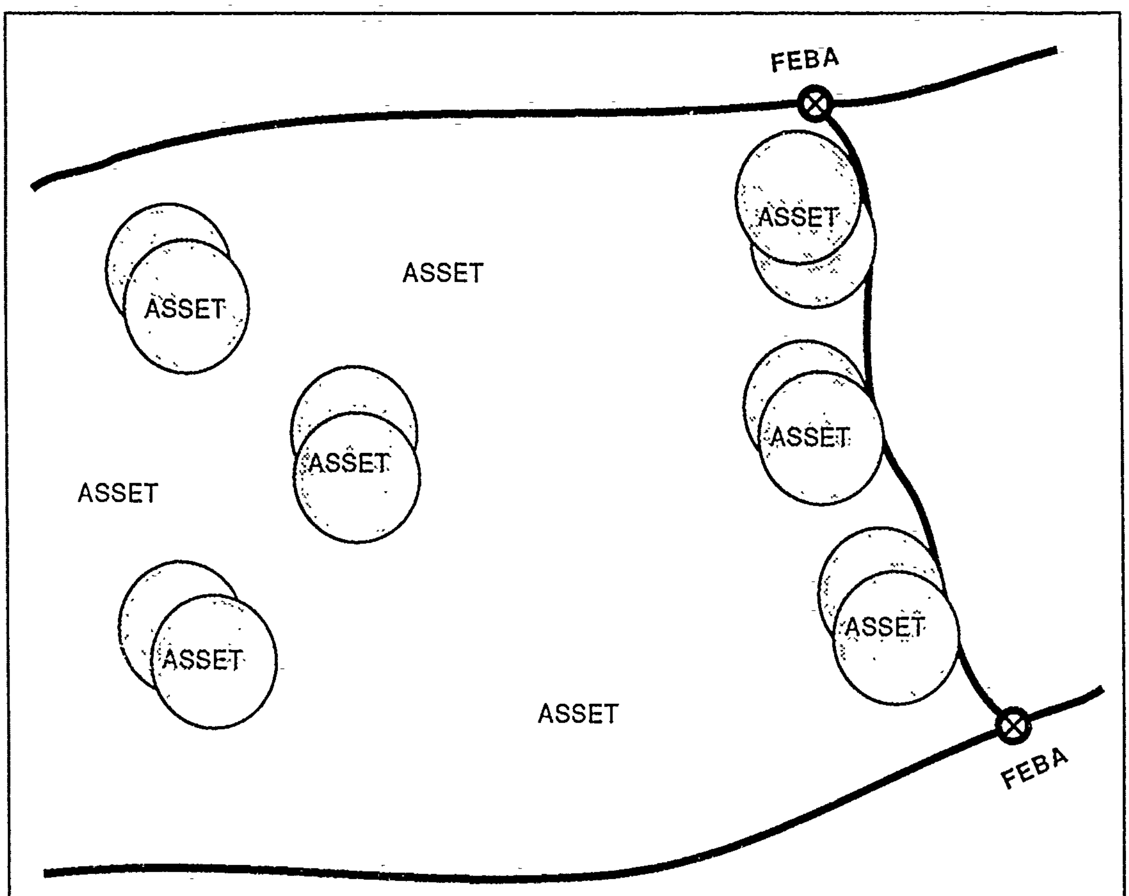



Figure 2. Balanced Defense

In the figure, the dark lines running across the top and bottom of the figure indicate a battle sector, or boundary. The line running between the two circles labeled FEBA is the Forward Edge of the Battle Area, or the dividing line between the friendly and enemy ground combat units. The term ASSET is used to depict resources that the commander wants protected from an enemy air attack. These assets could be maneuver units, support units, headquarters, fuel depots, or nuclear storage sites. The shaded circles enclosing some of the assets indicate the engagement envelope, or coverage provided by ADA units. Enemy aircraft would attack from right to left; if they fly into a shaded area they face a high probability of being fired upon. Notice that some of the assets are not covered. This is one of the consequences of having limited ADA resources.

*b. Forward Concentrated Defense*

The second strategy being analyzed in this thesis is the forward concentrated defense shown in Figure 3.

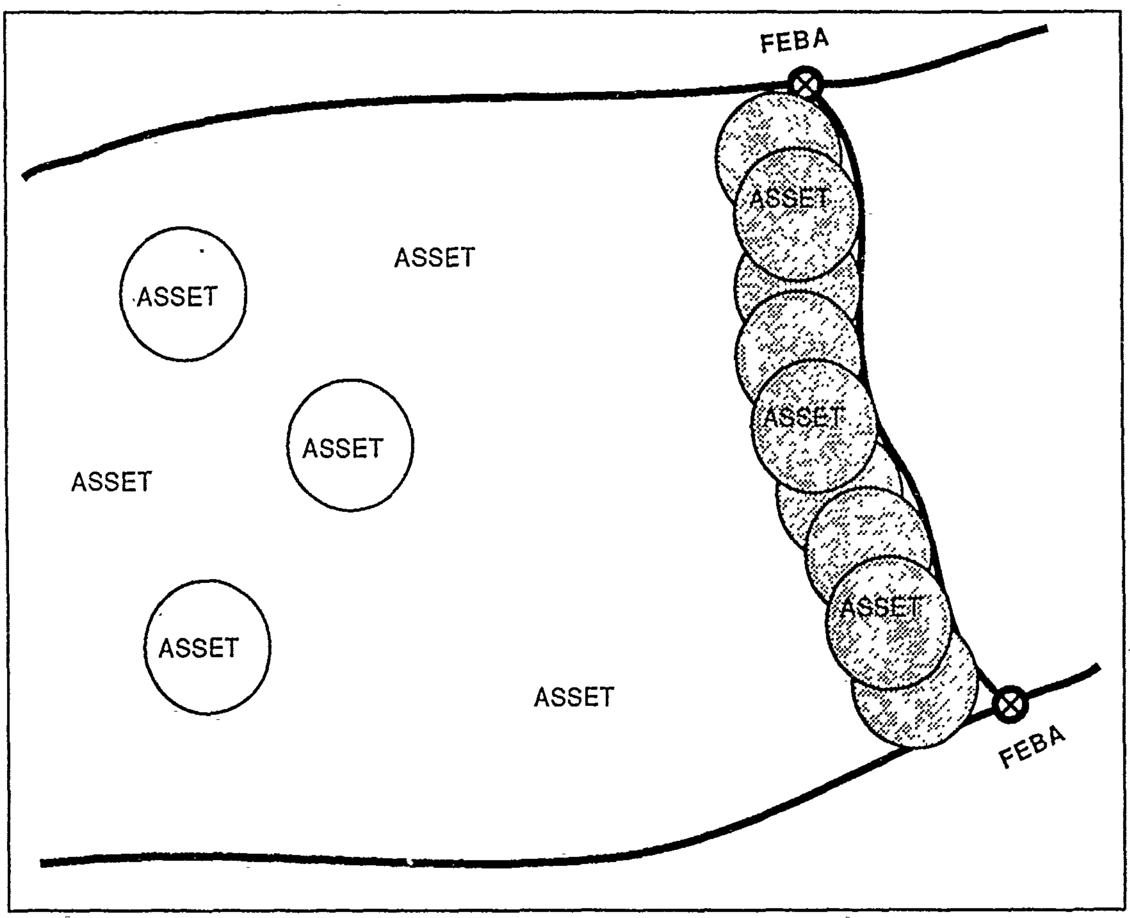



Figure 3. Forward Concentrated Defense

In this figure, the concept of belt defense is easily demonstrated. There are the same number of ADA units as shown in Figure 2 on page 4, but the majority of the units are concentrated near the FEBA. This creates a 'belt' of ADA coverage that an enemy plane must fly through in order to reach an asset. The advantage is that all of the assets are indirectly protected. The main criticism of the belt defense (that they can be defeated by flying around either end) can now be addressed. Imagine that the battle sectors above and below the one in Figure 3 also use a forward concentrated defense and that this goes on until such a location that there is no threat of an air attack. Obviously, the forward concentrated defense would not be viable on a small front such as Panama, or when invading the shores of enemy territory by sea; but, if effective, it could be used on a large land mass when the battle front is several hundred miles wide.

*c. Rear Area Concentrated Defense*

The third, and final strategy to be analyzed and compared is the rear area concentrated defense. In this defense, a point defense is used; however, the ADA units are predominantly located around assets well away from the FEBA. As shown in Figure 4 on page 7, this type of strategy looks very risky; the front-line assets are provided only minimum protection. This type of defense might be feasible if the rear area assets were of such vital importance that the additional coverage was justified. Justifiable situations could include a nuclear stockpile that a nation was preparing to use, or perhaps a nation defending a major metropolitan area, its own capitol, or strategic oil processing sites. In any case the rear area defense provides a strategy that should perform well against an air attack into the rear area.

## C. DESIRED MEASURES OF EFFECTIVENESS

Before deciding which particular computer simulation will be used to model the problem, measures of effectiveness (MOEs) should be discussed. Measures of effectiveness are quantitative values that allow model results to be evaluated to answer specific questions. In this thesis, MOEs will provide measures by which the three ADA defense strategies can be compared. As an air defender, the ultimate measure of success is to be able to answer "yes" to the following question: Did I adequately protect those assets that the ground forces commander wanted me to protect, thereby enabling him to accomplish his mission? There are, however, various degrees of success which can be quantified into the following desired measures of effectiveness:

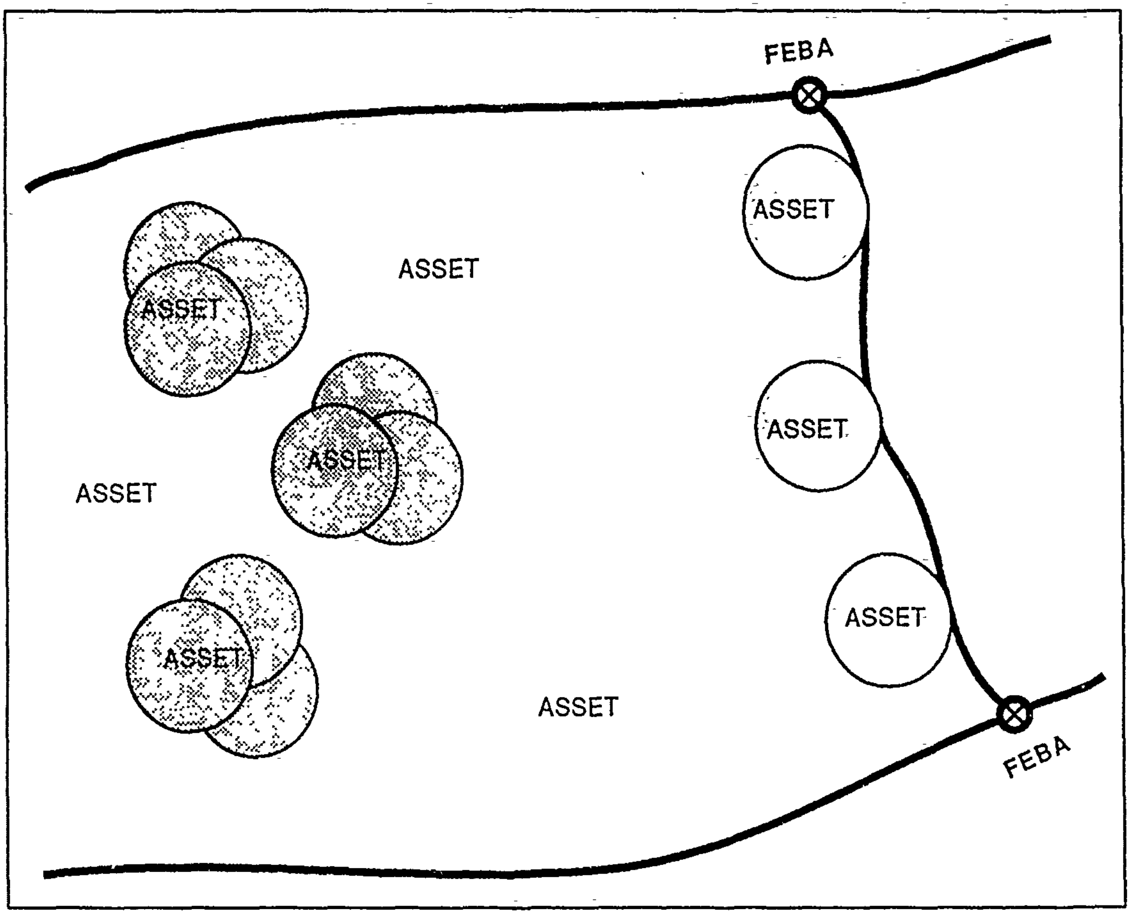



Figure 4. Rear Area Concentrated Defense

- Number of successful enemy air attacks.
- Amount of damage inflicted by enemy air attacks.
- Number of enemy planes shot down.
- Amount of damage sustained by ADA units.
- Amount of missiles/ammunition expended by ADA units.

1. Number of Successful Enemy Air Attacks

Using the number of successful enemy air attacks as an MOE captures the extent to which the enemy has air superiority. For purposes of this thesis, a successful air attack is achieved when an enemy aircraft releases his ordnance on an assigned target. If the number of air attacks varies daily, the percentage of successful enemy air attacks is a more useful figure. If the percentage is high, it means that either the enemy is attacking priorities that are not covered by ADA, or that the ADA coverage is not very effective.

2. Amount of Damage Inflicted by Enemy Air Attacks

This MOE is a more direct measurement of the effects of enemy air attacks, although it is much more difficult to quantify. Some sort of value must be agreed upon and placed on various kinds of personnel and equipment. Although this MOE and the previous one may appear to measure the same thing, a subtle difference exists. The enemy could have a high percentage of successful air attacks, but they could be inflicting minimum damage because they were bombing something which had a very low value, or because their ordnance was not very accurate or lethal.

3. Number of Enemy Planes Shot Down

This MOE is the all-time favorite, number one MOE for air defenders because once an enemy plane goes down in flames, it is virtually impossible for it to come back and attack in the future. Although the utility of this MOE can be questioned for a one-day war or for kamikaze air attacks by religious zealots, it is an excellent MOE for use in any scenario in which any aircraft is expected to make more than one attack. Once again, if the number of air attacks varies from day to day, this MOE would best be expressed as a percentage of planes launched or planes in inventory.

4. Amount of Damage Sustained by ADA Units

The amount of damage sustained by friendly ADA units is the polar opposite of the number of planes shot down. As ADA units are a major hurdle in the enemy's quest for a successful air attack, the enemy goes to great lengths to neutralize and destroy ADA sites. Their efforts range from air-to-surface missiles that home in on the ADA units radar signals, to air attacks designed specifically to locate and destroy ADA units (wild weasel missions). While an ADA unit is expected to repel enemy air attacks, it is also expected to survive so it can repel attacks the next day.

5. Amount of Missiles/Ammunition Expended by ADA Units

This MOE is meant to capture those ADA units that may not be damaged, but are unable to perform their mission due to a lack of missiles or ammunition. An ADA unit is expected to use its missiles efficiently. Possibly the most efficient use of a missile is to destroy a formation of attacking aircraft before they release their ordnance. In concert with the other MOEs, this MOE can measure efficiency. It can also be used to analyze and compare the strategies from a logistical point of view.

# II. THE MODEL

## A. SELECTING AN APPROPIATE MODEL

Because the battle scenario and the desired measures of effectiveness have already been determined, the process of selecting a particular computer simulation model with which to conduct the comparison of ADA strategies has been made easier. One model which seemed well-suited for this thesis is the Joint Theater-Level Simulation (JTLS). Described in detail later in this chapter, JTLS has one overwhelming advantage over all other computer simulation models similarly equipped: availability. JTLS is readily available for use in the Navy Wargaming Laboratory at the Naval Postgraduate School. Additionally, technical consultation was available from Edward P. Kelleher, an analyst and programmer who has had extensive experience with the design, programming and use of the JTLS model. This factor made the JTLS model particularly attractive for use in this thesis.

## B. JTLS BACKGROUND

JTLS is a computer-assisted simulation that models two-sided air, ground, and naval combat with logistical and intelligence support. It is designed as a theater-level model for use in the following areas:

1. The analysis, development, and evaluation of contingency plans and joint tactics.
2. The evaluation of alternative military strategies.
3. The analysis of combat systems.

The first JTLS model became operational in September, 1983. Now in its ninth release (Version 1.65C), JTLS is owned by the Force Structure, Resource, and Assessment Directorate (J-8) of the Joint Chiefs of Staff. The Joint Warfare Center at Hurlburt Field, FL has MAPP (Modern Aids to Planning Program) component project responsibility for JTLS, and the configuration management agency is the Joint Data Systems Support Center of the Defense Communications Agency. [Ref. 4: p. 2-1, Ref. 5]

In addition to its use at the Naval Postgraduate School, JTLS is used at the following locations: HQ US Atlantic Command, HQ US Special Operations Command, Marine Corps Wargaming & Assessment Center, National Defense University, HQ Republic of Korea-US Combined Forces Command, HQ US Central Command, HQ US

European Command, HQ US Southern Command, Joint Warfare Center, and the US Army War College. [Ref. 5]

## C. JTLS DESCRIPTION

### 1. System Support Hardware

JTLS is designed to run on VAX computers running the VMS operating system. To run JTLS with a reasonable execution time, the VAX computer must have at least eight million bytes of main memory, and approximately 500 million bytes of disk storage. Additionally, at least four DEC VT100-compatible terminals are required. In its maximum configuration, 26 such terminals are used. A graphics suite allows viewing unit locations, unit characteristics, along with terrain characteristics before and during JTLS execution. [Ref. 6: p. 4-1]

### 2. JTLS Software

Most of the JTLS source code is written in the SIMSCRIPT II.5 computer language. The "C" programming language, developed by Bell Laboratories, is used in the development of JTLS databases and the graphics programs that drive the graphics displays. A few subroutines in the graphics program are written in FORTRAN. [Ref. 6: p. 4-3]

### 3. JTLS Game Phases

In the JTLS System, the wargaming process is divided into four game phases: initialization, preparation, execution, and analysis. Each game phase consists of one or more programs or systems which allow user interface with the system.

#### *a. Initialization*

During the initialization phase, the Scenario Development System is used to create a JTLS database, a very time-consuming and extensive task. The JTLS database is divided into two parts: the terrain file and the scenario data file. The terrain file contains an exhaustive amount of data relating to the terrain on which the game is held. The European database, used for this thesis, contains over 80,000 coded terrain hexagons. Each JTLS hexagon represents an imaginary hexagon on land measuring 16.5 kilometers from side to side. A hexagon is coded with elevation and one of 15 possible terrain types. Some of the additional data associated with a hexagon include the barriers and target types located within the hexagon. The scenario data file contains the following types of data:

1. General modeling parameters that affect the mathematical and logical algorithms used to model the operations of theater level military forces.

2. Unit and unit force structure data, such as organizational structure, assigned combat and combat support equipment, ordnance, and logistics.

3. Target data that describe militarily significant objects that can interact with a military unit as it conducts its combat operations, such as bridges and runways.

Due to the popularity of the Fulda Gap s[illegible] among military modelers, the creation of a scenario data file for this thesis was [illegible] easier than it could have been, in that a scenario with US and Soviet forces [illegible] P[illegible]ton Scenario' already existed in the JTLS directory. Minor modifications, such as unit location and certain modeling parameters were made to the 'Patton Scenar[illegible]' data file and it was used for the comparative analysis. [Ref. 6: pp. 2-1 - 2-4]

*b. Preparation*

The preparation phase uses the JTLS Executive System. The JTLS Technical Coordinator uses this system to start and restart the game, configure the exercises, and manage the directories (general housekeeping of files, and making tape backups as necessary). [Ref. 4: pp. 2-2]

*c. Execution*

During the execution phase of the game, The Combat Events Program (CEP) 'fights the war' while the Model Interface Program (MIP) allows the Controller and Game Players to interface with the CEP.

> The CEP is the central program of the JTLS system, the combat model. It determines all of the actions and interactions among the air, land, and naval forces defined and modeled for the specific scenario being run. The CEP creates, maintains, and reports the current status of the warfare environment being modeled. [Ref. 4: pp. 2-4]

Through the MIP, "Players direct the forces under their command by creating and sending orders to the CEP. The MIP provides the players with a menu-driven environment from which these orders can be created and sent." [Ref. 4: pp. 2-4]

*d. Analysis*

The analysis phase of the JTLS game uses the JTLS Postprocessor System to aggregate information on game results and to produce reports, charts, and graphs. The Postprocessor System is currently undergoing a major redesign effort and was not used with this thesis due to incomplete postprocessor files in version 1.65C of JTLS [Ref. 4: pp. 2-6b]. The data for 'postprocessing-by-hand' was obtained through periodic summary reports generated by the Combat Events Program.

4. JTLS Staffing

Five different types of staff positions are required in order to run the JTLS model:

1. Director--Plans and administers the wargame.
2. Technical Coordinator--Starts and restarts the game, and provides computer expertise to the game control staff.
3. System Manager--Configures the computer system in preparation for the installation of the JTLS model.
4. Controller--The game monitor. He has the capability to stop the game, change game parameters, take checkpoints, and alter the game speed.
5. Players- RED and BLUE. Have command of forces on their respective side. [Ref. 6: pp. 2-5]

Due to the individualized, and independent nature of thesis research, the author learned how to perform, and then subsequently performed all of the functions, except for number three, himself. The System Manager function was not needed, as the computer in the Navy Wargaming Laboratory was already configured to run JTLS.

# III. SCENARIO DEVELOPMENT

## A. GENERAL DESIGN

### 1. Independent Variables

A major part of the JTLS exercise design has already been determined by choosing the three different ADA strategies to be compared. What about the makeup of the opposing (Soviet) air force? In the Patton scenario of the JTLS model, the Soviet air force in the Fulda Gap consists of 202 airplanes divided among three airbases. Although it is agreed that sending all 202 airplanes to attack at one time or in one day is not a wise strategy, a sufficient number of airplanes need to attack in order to fully tax the US air defenses. The number of airplanes that was decided upon was 174, or approximately 86% of 202. To enable the comparison of ADA defense stratgies to be robust with respect to Soviet attack strategies, two exercise design variables were introduced:

1. Location of Attack -- This variable can be one of two variants. The Soviet airplanes can attack targets along the FEBA (ground troops and equipment), or they can attack targets in the rear area (airbases).
2. Air Raid Mission Size -- The Soviets can attack with a few missions consisting of a large number of airplanes, or they can attack with many missions consisting of a small number of aircraft.

For the second design variable, although the number of planes in a mission changes, the total number of planes that attack in one day remains constant, as does the total number of planes that actually conduct the bombing. The factor that is different between the missions is the size of the escort force. The escort force for a bombing mission generally consists of:

1. Air-to-air fighters, whose job it is to eliminate the opposing force interceptors sent to shoot down the bombers.
2. Jammers, who disrupt the opposing forces air defense radars by electronic and other means.
3. Wild Weasels, which take a more direct approach than the jammers by attacking air defense sites with ordnance.

The Soviet commander can have either a large escort force, thereby increasing the probability of a successful bombing attack but decreasing the the number of targets bombed, or he can have a small escort force with which he can attack many targets, but at a greater risk. Because the size of the escort force is the determining factor in the air raid mission size, the second exercise design variable will be called 'escort size.' The three independent exercise design variables (ADA defense strategy, Location of Attack, and Escort Size) interact to form 12 combinations. A visual representation of these combinations is displayed as a three-dimensional scenario design matrix in Figure 5 on page 15. In the figure, each combination is represented by a block, or cell. Each cell corresponds to a unique scenario that must be programmed into the JTLS model, run and analyzed. The cell that is shaded represents a forward concentration ADA defense facing a rear area Soviet attack with a large escort size. The design matrix shows the range over which the three ADA strategies will be compared. A strategy which works well with one of the 'columns' of the matrix may not be the best choice for another.

2. Available MOEs

To determine which ADA strategy is the best choice given the Soviet attack options, MOEs will be used. Three of the five MOEs discussed in "C. DESIRED MEASURES OF EFFECTIVENESS" on page 6 will be used.

*a. Number of Enemy Planes Shot Down*

This MOE will be referred to as MOE #1: Soviet Airplanes Shot Down by US ADA. This information is readily available from the JTLS Periodic Summary Report which lists the number and type of planes shot down by ADA. Information on which ADA unit shot the plane down is not available.

*b. Number of Successful Enemy Air Attacks*

Further defined as MOE #2 (Percentage of Successful Soviet Bombing Missions) this MOE is available from JTLS as the number of aircraft that delivered weapons. In JTLS, an aircraft delivers its weapons if it finds a predetermined target type along its designated bombing route. To prevent the act of finding a target from becoming a source of variation, each bombing mission was given exact information on the location of its target. Thus, if an aircraft reached its target, it delivered its weapons.

*c. Amount of Damage Inflicted by Enemy Air Attacks*

This information is captured in MOE #3: Number of US Ground-Targets Destroyed. In the JTLS rear area scenario the assets that are attacked are the US airbases at Koblenz, Frankfurt, and Kaiserslautern. The target types that are designated are US airplanes. Because JTLS records the number of airplanes lost on the ground due to air attack, this is a feasible MOE. For personnel, tanks, and lightly armored vehicles along the FEBA, JTLS does not specifically record the damage caused by air attacks,

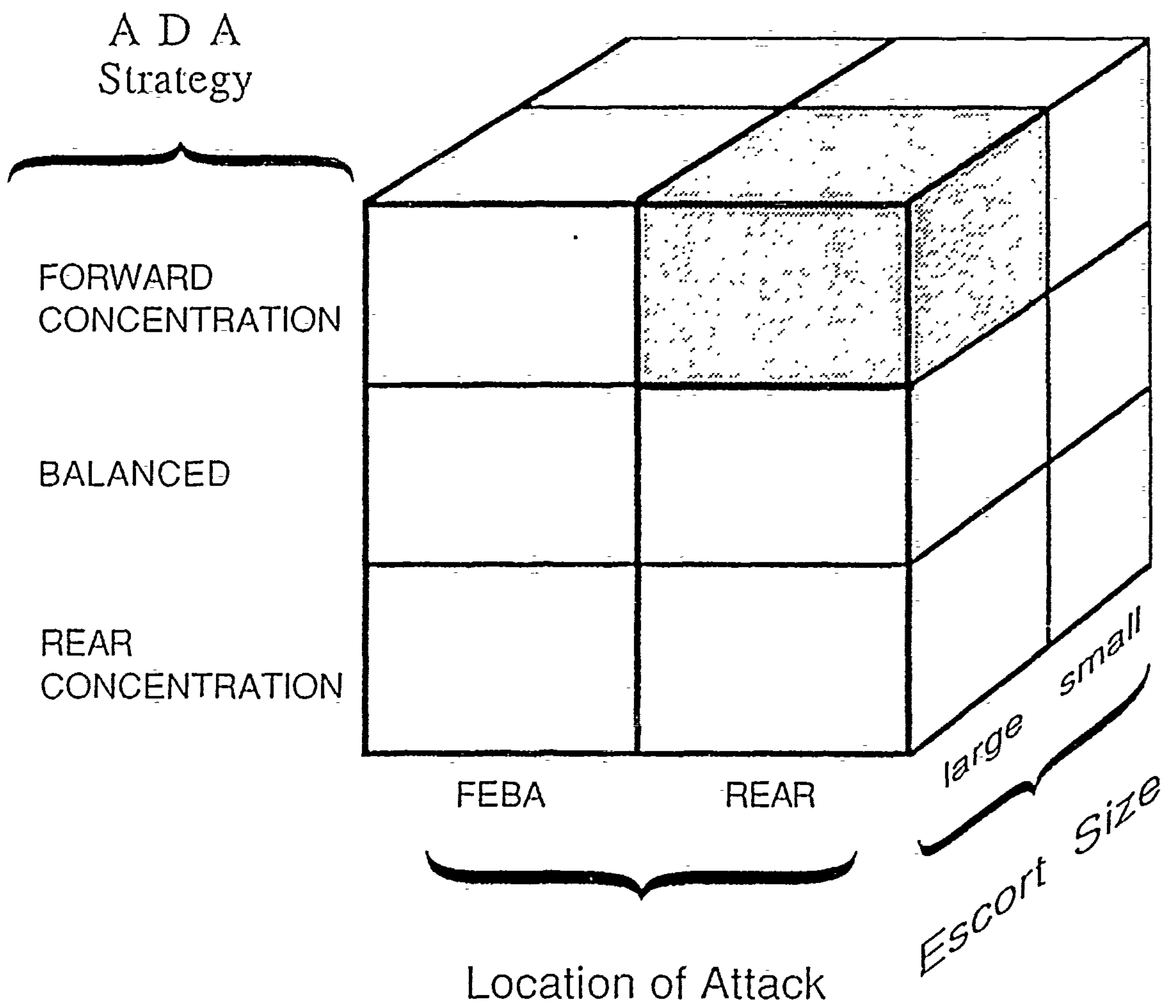



Figure 5. Three-Dimensional Scenario Design Matrix

nor is it easily available by modifying the model code. For this reason, MOE #3 will be defined only for attacks on the rear area.

*d. Amount of Damage Sustained by ADA Units*

Because JTLS does not separate the damage caused by air attacks from ground combat, data concerning this MOE are also not available. The actual results of the scenario runs were investigated, and the 'current strength' of the ADA units at the end of the day's attacks was always above 95%, indicating that little or no permanent damage was sustained by ADA units.

*c. Amount of Missiles/Ammunition Expended by ADA Units*

This MOE is not extractable from the current version of JTLS. JTLS records the tonnage of ammunition expended during a reporting period. This includes ammunition from all weapons systems, incuding air defense systems. An unsuccessful attempt was made to modify the code to separate the ADA ammunition from the other weapons systems. Future versions of JTLS are expected to be able to report this MOE as rounds, missiles fired by individual ADA units.

3. Scenario Limitations

*a. Logistics*

The length of each scenario was kept to one day because of the increased complexity of running the logistics functions in JTLS for wars in excess of one day. Also, the lack of availability of logistical data and unit damage data for ADA units decreased the value of the benefits of running the scenarios for a longer period of time.

*b. US Air Force*

Although JTLS is normally run using the air forces of both sides, for a 'pure' analysis of ADA defense strategies the US Air Force was not played; except to provide ground-targets for Soviet air attacks. Incorporating the air force into the scenarios would make the effort of programming the scenarios into the JTLS model extremely difficult and time-consuming, and it would force the introduction of two or three more independent variables. This could easily increase the number of possible scenarios to 36 or more, resulting in a programming and analysis effort beyond that of this thesis research.

*c. Number of JTLS Runs*

Five runs were made for each of the twelve scenarios. This number allowed for statistical testing of hypotheses at the $\alpha = 0.10$ level while maintaining the time spent executing the runs to a reasonable amount.

## B. DESCRIPTION OF GROUND FORCES

The ground war was constructed to be as constant a factor as possible throughout all scenarios. The beginning location and strength of every unit was the same in every scenario. Identical sets of orders were issued to the same units in each scenario. The only thing that differed was the independent variable: the location of the ADA units.

The locations of the major US and Soviet combat units are shown on the map of the Fulda Gap area in Figure 6 on page 18. A more detailed list of units and locations is contained in Appendix A. In the ground war, the 2d and 4th Armored Divisions are ordered to conduct the main attack across the Fulda river to capture the terrain currently held by the 12th Motorized Rifle Division. The 8th Infantry Division is ordered to conduct a secondary attack in the south; thereby clashing with the 14th Motorized Rifle Division and not allowing it to reinforce the defense against the main attack in the north. The 9th Infantry Division is ordered to move into position behind the 8th Infantry Division, and prepare to support either the main or secondary attack, as needed. The Soviet 12th and 14th Motorized Rifle Divisions are ordered to defend in place while the 10th Tank Division moves to reinforce the defense against the main attack.

## C. DESCRIPTION OF ADA UNITS

The locations of ADA units in the forward concentration, balanced, and rear area concentration defense scenarios are depicted in Figure 6 on page 18, Figure 7 on page 19, and Figure 8 on page 20, respectively. The units are represented by engagement envelope circles. A detailed list containing units and their exact locations in each of the three types of defenses is contained in Appendix B.

## D. DESCRIPTION OF AIR FORCES

### 1. Maximum Escort Raid

The maximum escort raids consist of nine bombing missions taking place over a seven-hour period. Each bombing mission contains:

- twelve to fifteen bomber aircraft
- two electronic countermeasures (jammer) aircraft
- eight air defense suppression (wild weasel) aircraft
- five air-to-air fighter aircraft.

### 2. Minimum Escort Raid

There are eighteen bombing missions in a minimum escort raid. The composition of a bombing mission is:

- four to five bomber aircraft
- one electronic countermeasures (jammer) aircraft
- two to three air defense suppression (wild weasel) aircraft
- two air-to-air fighter aircraft.

A detailed listing of maximum and minimum escort attacks including composition, attack times, and targets is in Appendix C.

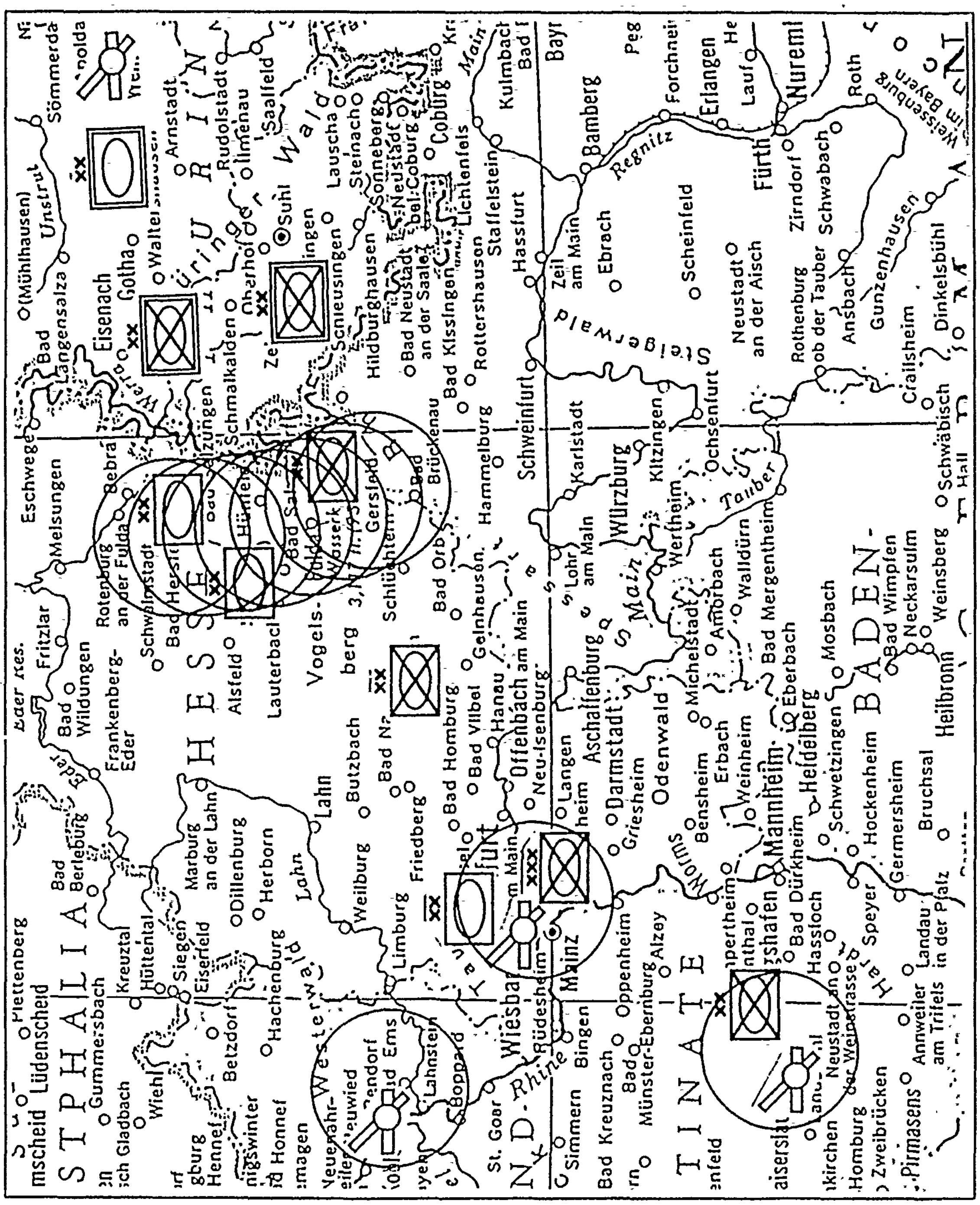



Figure 6. Beginning Scenario Ground Situation with Forward Concentration Defense

Source: Hamond, C.S. & Co., *Ambassador World Atlas*, New York, NY.

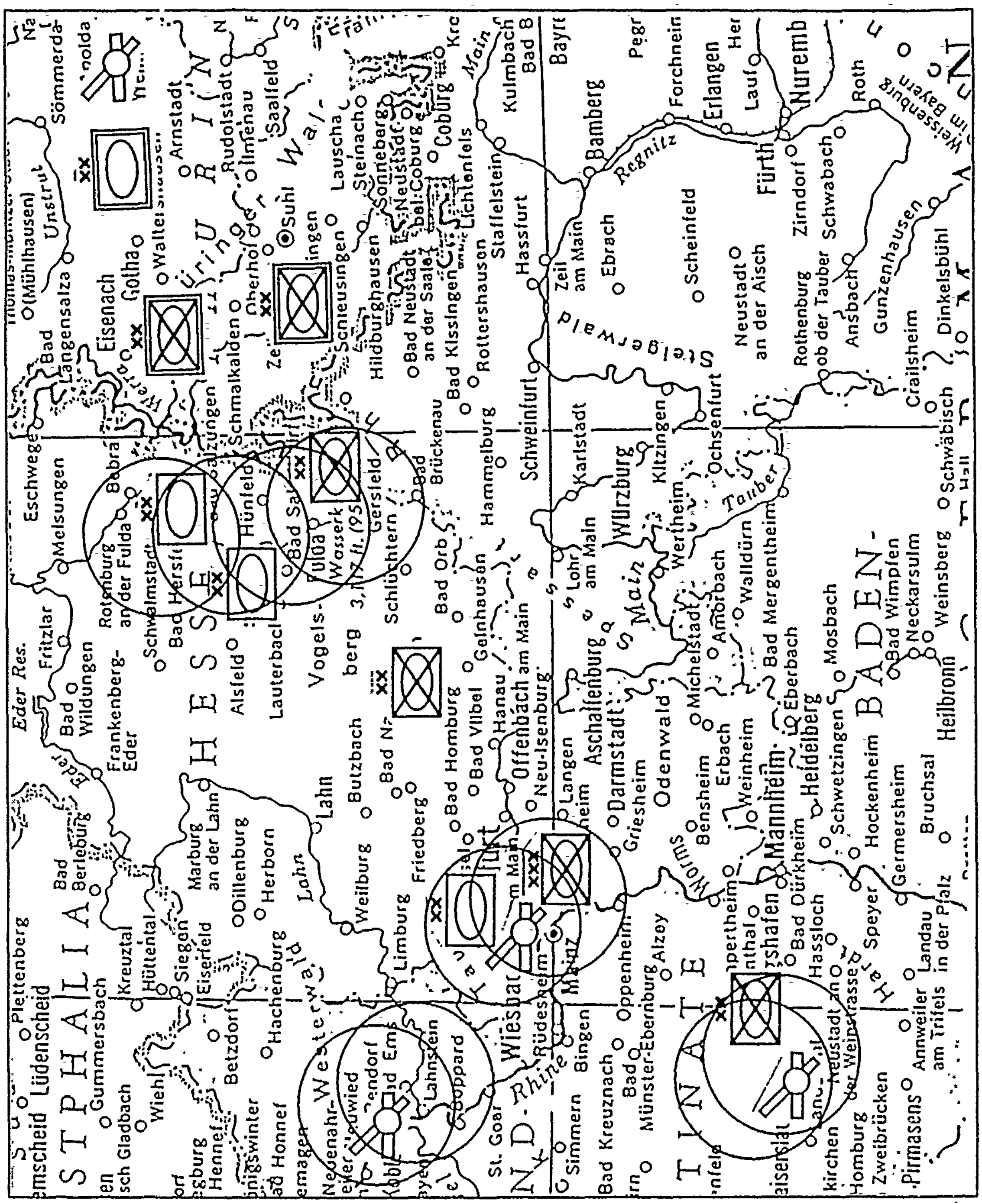



Figure 7. Beginning Scenario Ground Situation with Balanced Defense
Source: Hamond, C.S. & Co., *Ambassador World Atlas*, New York, NY.

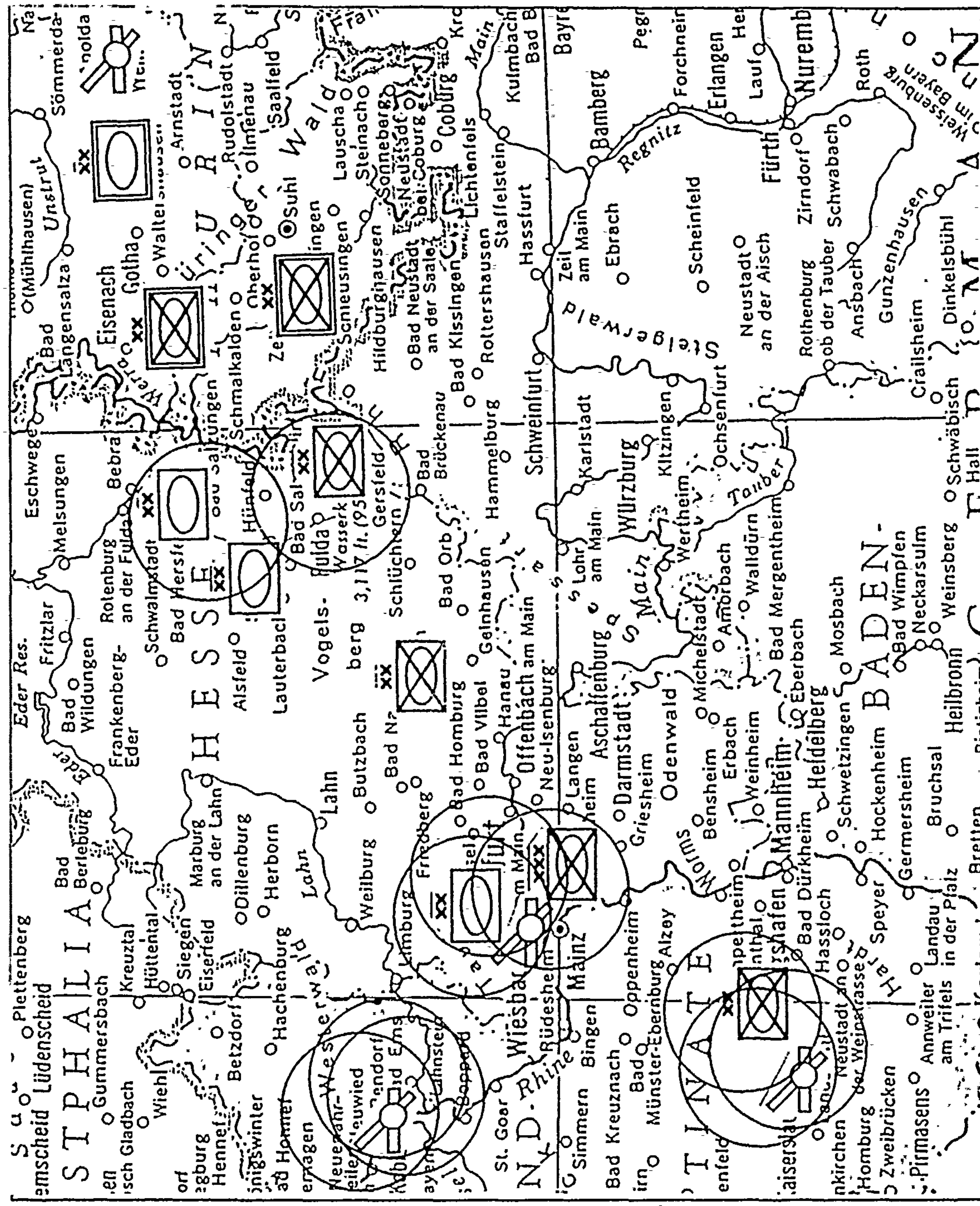



Figure 8. Beginning Scenario Ground Situation with Rear Area Concentration Defense

Source: Hamond, C.S. & Co., *Ambassador World Atlas*, New York, NY.

### 3. Attack Areas

The location of the aircraft silhouettes in Figure 9 on page 22 show the general locations of a FEBA attack. Figure 10 on page 23 depicts the aircraft attacking the airbases in the rear area. The actual targets for both areas of attack are listed in Appendix C.

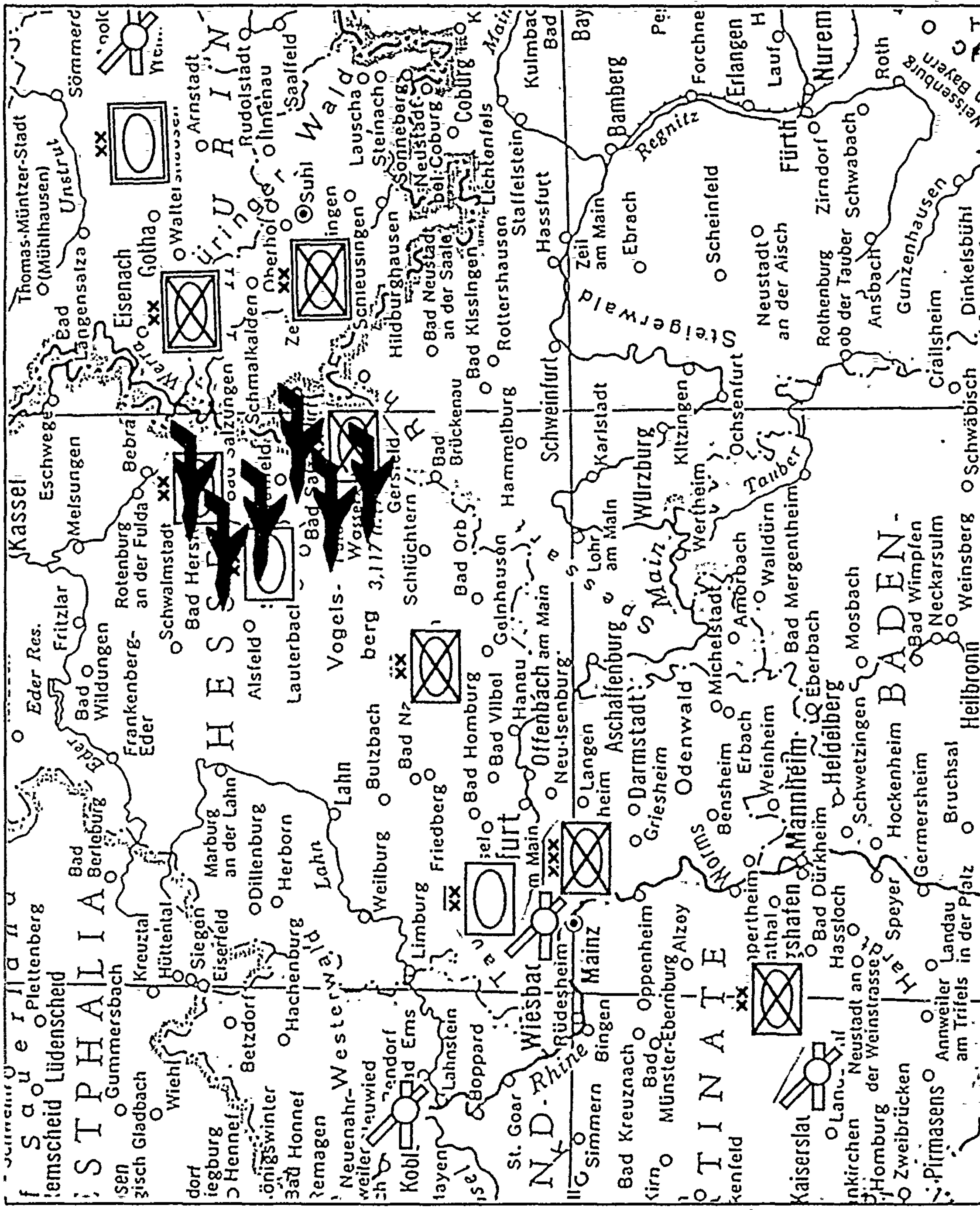



Figure 9. Beginning Scenario Ground Situation with FEBA Attack

Source: Hamond, C.S. & Co., *Ambassador World Atlas*, New York, NY.

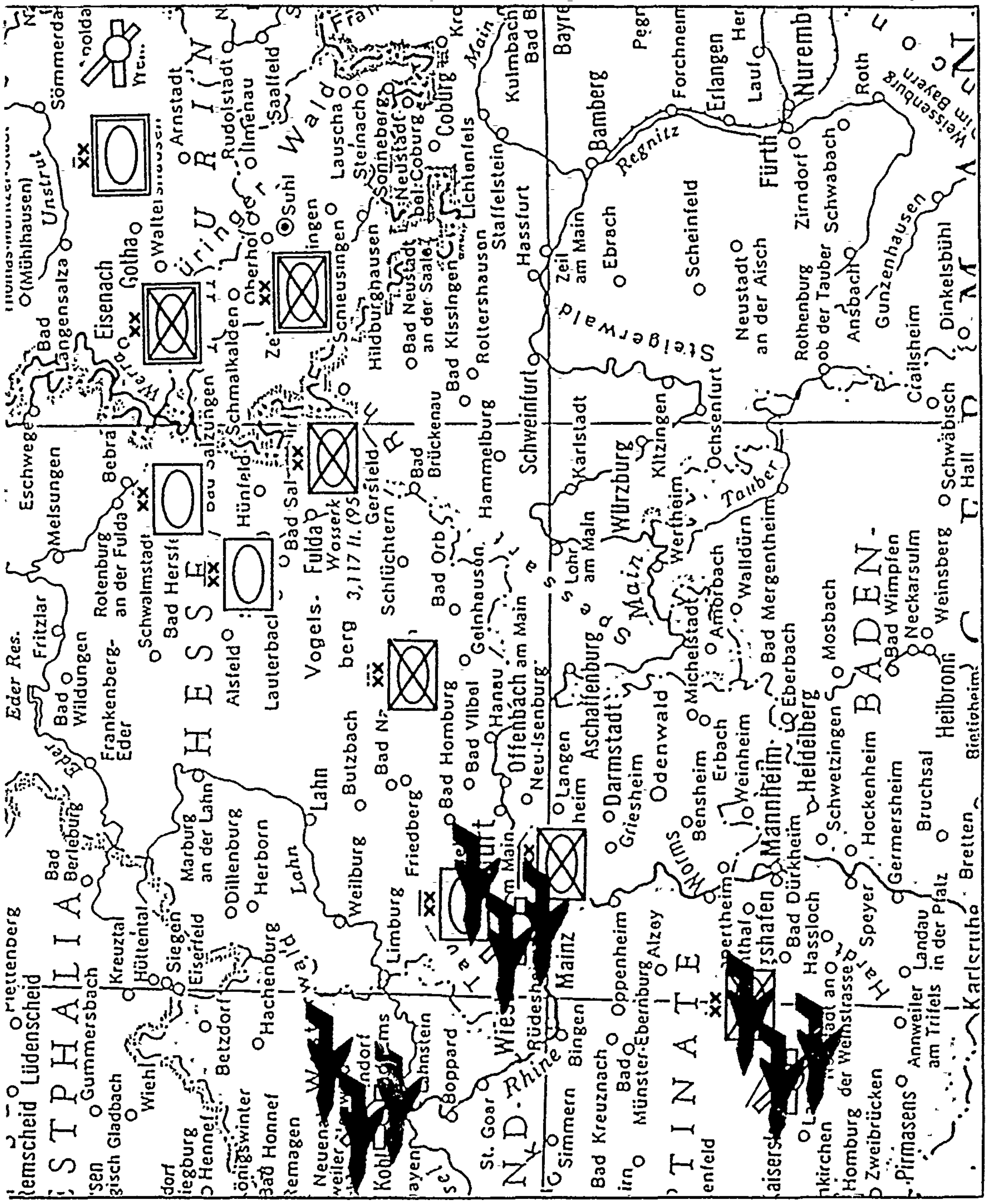



Figure 10. Beginning Scenario Ground Situation with Rear Area Attack
Source: Hamond, C.S. & Co., *Ambassador World Atlas*, New York, NY.

# IV. MODEL RESULTS AND ANALYSIS

The data produced by the sixty runs of the JTLS model were collected and processed. The results and the analysis of the results are presented in terms of each MOE. The tables containing the results show the MOEs by run number for each of the twelve scenarios. The sample mean and sample standard deviation are also presented for each scenario.

## A. MOE #1: SOVIET AIRPLANES SHOT DOWN BY US ADA

Table 1 shows the simulation results for MOE #1.

Table 1. SIMULATION RESULTS FOR MOE #1: Soviet Airplanes Shot Down by US ADA

| Type of ADA Defense | Location of Air Attack | Escort Size | Run #1 | Run #2 | Run #3 | Run #4 | Run #5 | Sample Mean | Sample Std. Dev. |
|---|---|---|---|---|---|---|---|---|---|
| Forward Concentration | FEBA | Large | 8 | 6 | 8 | 9 | 16 | 9.4 | 3.9 |
| | | Small | 45 | 51 | 46 | 38 | 46 | 45.2 | 4.7 |
| | Rear Area | Large | 108 | 93 | 125 | 101 | 105 | 106.4 | 11.8 |
| | | Small | 148 | 152 | 153 | 151 | 147 | 150.2 | 2.6 |
| Balanced Defense | FEBA | Large | 1 | 2 | 1 | 3 | 1 | 1.6 | .89 |
| | | Small | 1 | 4 | 4 | 3 | 1 | 2 | 1 |
| | Rear Area | Large | 73 | 72 | 65 | 72 | 67 | 69.8 | 3.6 |
| | | Small | 134 | 118 | 138 | 124 | 130 | 128.8 | 8 |
| Rear Area Concentration | FEBA | Large | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Small | 0 | 0 | 0 | 1 | 0 | .2 | .45 |
| | Rear Area | Large | 61 | 55 | 61 | 66 | 74 | 63.4 | 7.1 |
| | | Small | 126 | 118 | 135 | 133 | 130 | 128.4 | 6.7 |

1. Soviet attack upon the FEBA

When analyzing data, it is frequently helpful to start by using a graphical method. A graph can quickly convey insights that are not readily available through a table of data (such as Table 1). One type of graph which allows a quick comparison of the ADA strategies through the MOE results is a box plot. Box plots convey a sense of location and scale through which a comparison can be made. The box plots for the results of a large and small escort attack on the FEBA are illustrated in Figure 11 and Figure 12 on pages 25 and 26, respectively. Appendix D contains a succinct explanation of the symbols used in the box plots. It is quite apparent that the forward concentration defense does a much better job of shooting down aircraft than the other two strategies. One would have expected these results, due to the fact that the forward concentrated defense has more ADA units in the area of attack than the others. Still, some measure of validation can be accredited to a model that produces results in line with intuitive thinking.

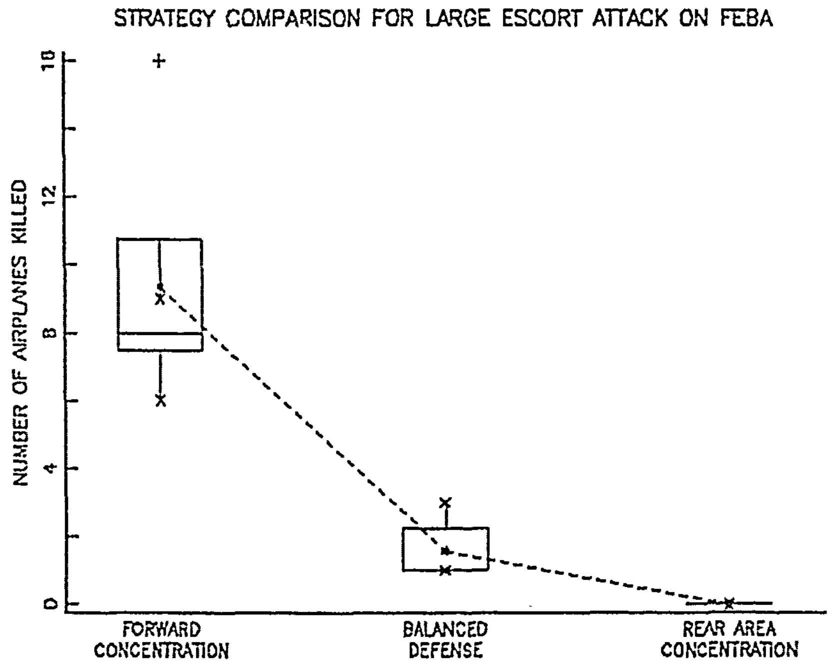



Figure 11. Box Plot Showing MOE #1 Results for Large Escort Attack on FEBA

It is one thing to graphically show that the forward concentration defense is better than the others; it is quite another to prove it statistically. In each scenario, an MOE can be thought of as a random variable. A run of the scenario results in a realization of that random variable, and each random variable has an associated probability density function. With such a small sample size (five runs) for each scenario, it would be incorrect to assume that the number of planes shot down for each strategy has a normal distribution, or for that matter, has any particular distribution.

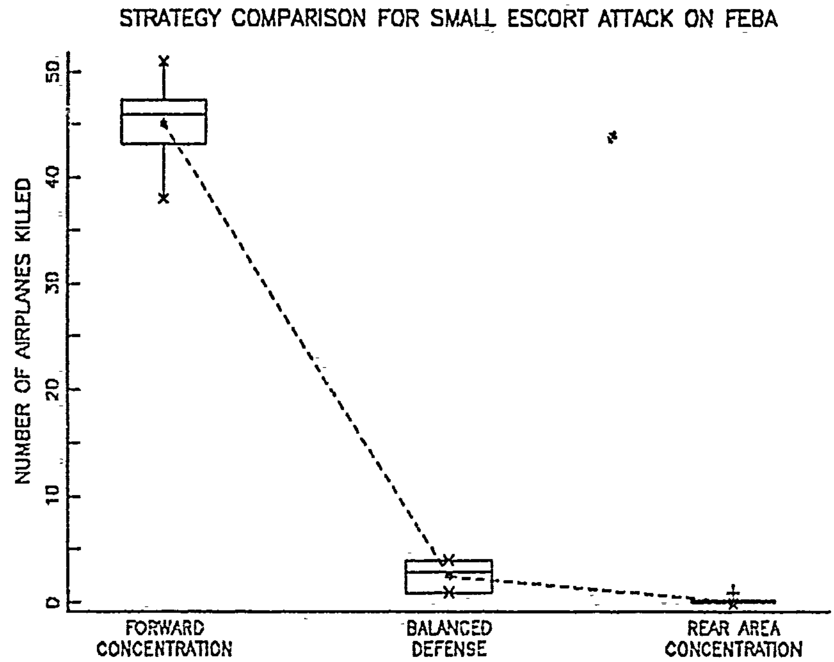



Figure 12. Box Plot Showing MOE #1 Results for Small Escort Attack on FEBA

What is needed, then, is a nonparametric (distribution-free) test that detects differences in location parameters. The Mann-Whitney-Wilcoxon test, which is often used for this purpose, assumes that the probability functions of the random variables have identical variances [Ref. 7: p. 159]. Examination of the data and the box plots show that this assumption is not valid. The Wilcoxon signed rank test is a more general nonparametric test that does not require the equality of variances assumption [Ref. 7: p. 123]. It is also appropriate to use because the data is paired; the $i^{th}$ run of every scenario uses the same random number seeds. The Wilcoxon signed rank test uses the sign and the magnitude of the difference between samples of two random variables to detect a difference in the median of the random variables. As applied to MOE #1 for large escort attacks on the FEBA, the corresponding hypotheses for the Wilcoxon signed rank test are:

Null Hypothesis: There is no difference between a forward concentration and a balanced defense as measured by the medians of the number of airplanes killed by each strategy for a large escort attack on the FEBA.

Alternative: There is a difference; the forward concentration kills more airplanes than the balanced defense.

and,

Null Hypothesis: There is no difference between a forward concentration and a rear area concentration defense as measured by the medians of the number of airplanes killed by each strategy for a large escort attack on the FEBA.

Alternative: There is a difference; the forward concentration kills more airplanes than the rear area concentration defense.

The level of statistical significance that will be used with this (and subseqent) applications of the sign test is $\alpha = 0.10$ i.e., the probability of rejecting the null hypothesis when it is really true is 0.10. When the Wilcoxon sign test is applied in this manner, the null hypothesis is rejected in the two inferences above.[2] The forward concentration defense produces the best results in terms of MOE #1.

2. Soviet attack upon the Rear Area

The box plots for a large and small escort attack on the rear area are in Figure 13 on page 28. The number of airplanes killed is a dramatic increase from those resulting from attacks on the FEBA. This is probably because the airplanes have to fly through more ADA coverage to reach their targets in the rear. When attacks are made along the FEBA, the airplanes only have to fly through minimum coverage because the ADA units are deployed at least 30 kilometers behind the FEBA (where the assets are located) due to tactical considerations. The ADA coverage for the assets in the rear area are able to deploy well forward of the asset, insuring increased time for airplanes to be detected and engaged.

Although the forward concentration strategy appears to be better than the other two strategies for both a large and small escort attack, the difference is not as pronounced as that of an attack on the FEBA. When the Wilcoxon sign test procedures are applied to these scenarios, the null hypothesis of equal medians of strategies is rejected. The conclusion is made that for Soviet attacks on the rear area, the forward concentration defense is superior to the balanced or rear area concentration defense with respect to MOE #1. Coupled with the results from Soviet attacks on the FEBA, if the number of airplanes killed was the only consideration, the forward concentration defense

[2] Appendix E contains details for the computation of the test statistic used in these hypotheses.

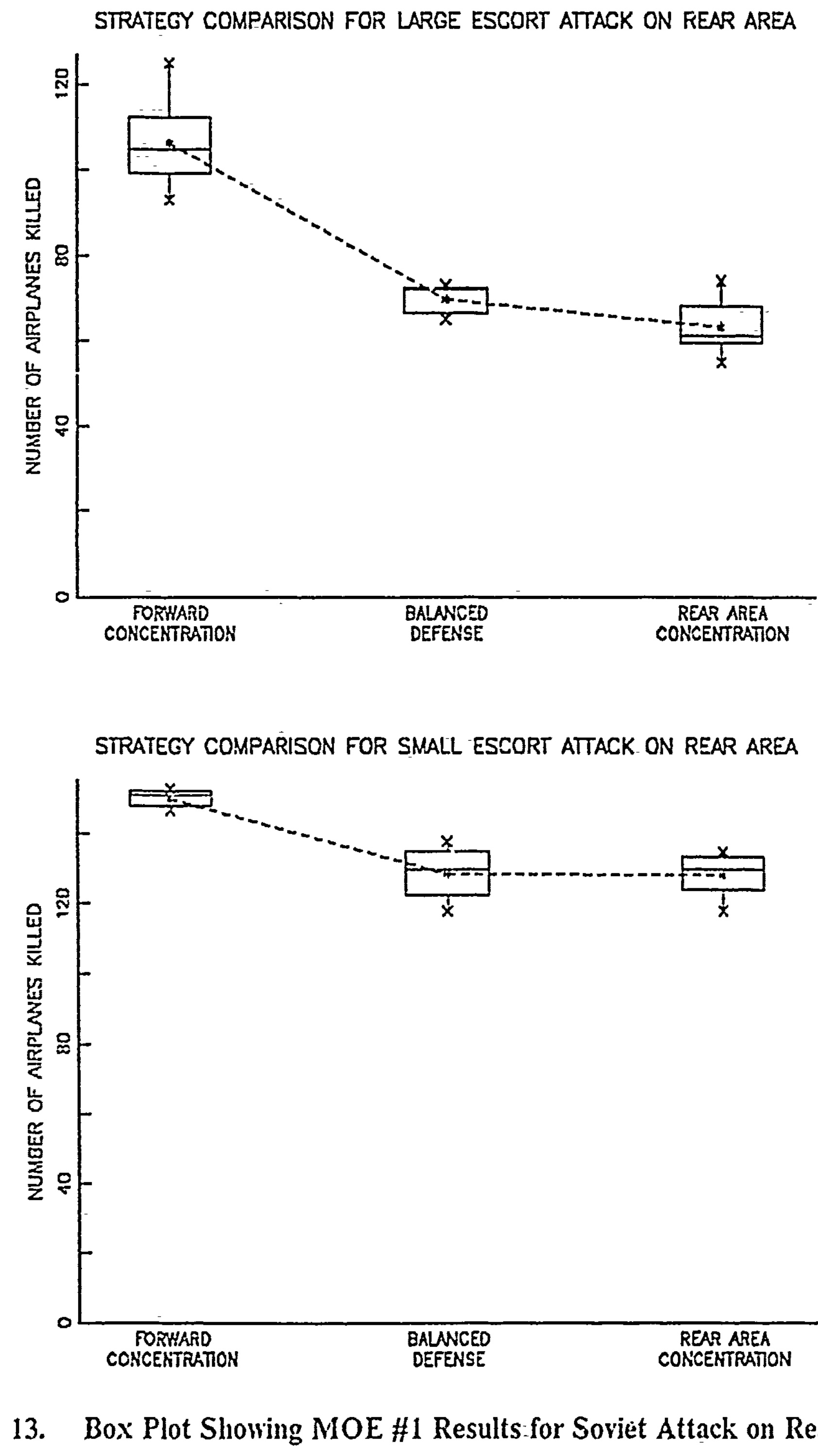



Figure 13. Box Plot Showing MOE #1 Results for Soviet Attack on Rear Area

would be the strategy of choice for the US commander, regardless of the choice that the Soviet commander made. Figure 14 is a skyscraper plot that brings the twelve scenarios together for an overall comparison. The height of the skyscrapers are the sample means of the number of airplanes killed in each scenario. The dominance of the forward concentration strategy regardless of the Soviet attack options is very evident.

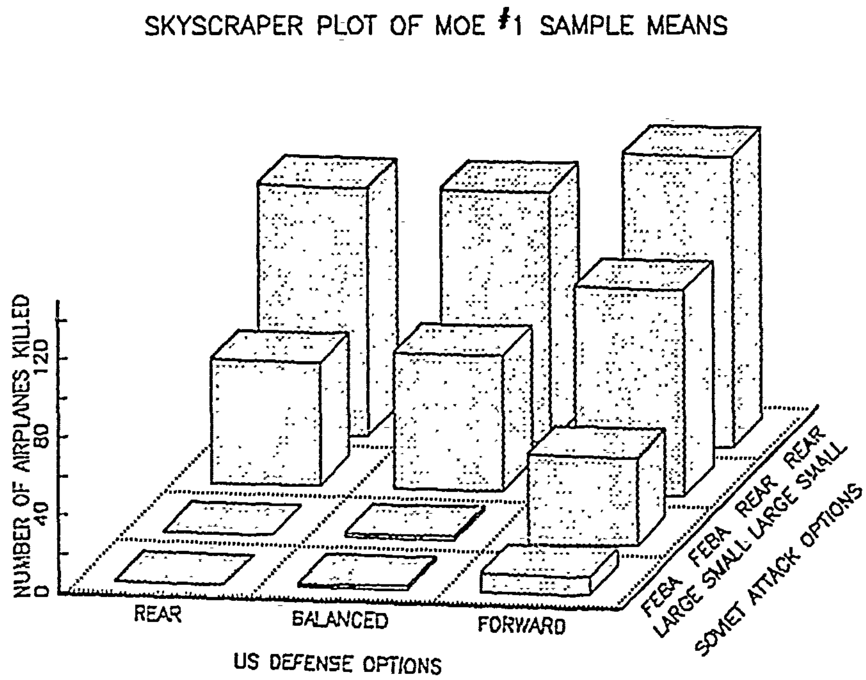



Figure 14. Overall Comparison of Options with MOE #1 Results

## B. MOE #2: PERCENTAGE OF SUCCESSFUL SOVIET BOMBING MISSIONS

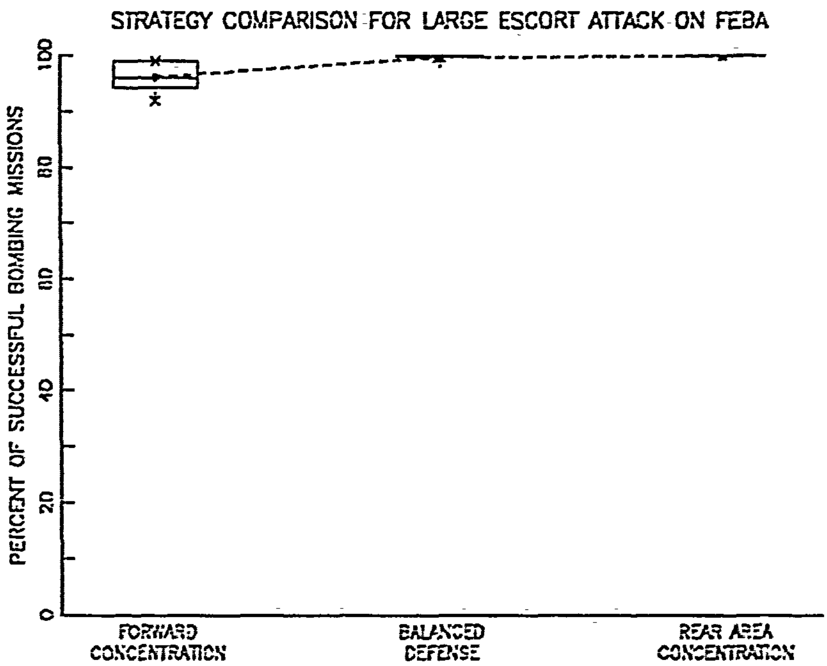
Table 2 on page 30 shows the simulation results for MOE #2. For this measure of effectiveness, lower percentages are better that higher ones. When examining Table 2, notice the extremely high percentages for successful missions when the FEBA is attacked. In view of the results from MOE #1, however, these high percentages should be expected. The number of planes shot down during FEBA attacks was very low. Also, consider the fact that a plane can be shot down on a successful bombing mission as long as it is shot down after it delivers its ordnance. This would account for the percentages that still seem to be high even when factoring in the number of planes shot down.

The box plots for the scenario results in terms of MOE #2 are shown in Figure 15 on page 31, and Figure 16 on page 32. The plots display the high percentages for attacks on the FEBA very effectively. They also show that the percent of successful

Table 2. SIMULATION RESULTS FOR MOE #2: Percentage of Successful Soviet Bombing Missions

| Type of ADA Defense | Location of Air Attack | Escort Size | Run #1 | Run #2 | Run #3 | Run #4 | Run #5 | Sample Mean | Sample Std. Dev. |
|---|---|---|---|---|---|---|---|---|---|
| Forward Concentration | FEBA | Large | 95 | 96 | 99 | 99 | 92 | 96.2 | 2.9 |
| | | Small | 78 | 77 | 79 | 85 | 85 | 80.8 | 3.9 |
| | Rear Area | Large | 43 | 51 | 33 | 43 | 42 | 42.4 | 6.4 |
| | | Small | 19 | 17 | 12 | 14 | 20 | 16.4 | 3.4 |
| Balanced Defense | FEBA | Large | 99 | 100 | 100 | 100 | 100 | 99.8 | .45 |
| | | Small | 100 | 96 | 91 | 96 | 99 | 96.4 | 3.5 |
| | Rear Area | Large | 56 | 49 | 60 | 48 | 56 | 53.8 | 5.1 |
| | | Small | 33 | 35 | 27 | 22 | 36 | 30.6 | 5.9 |
| Rear Area Concentration | FEBA | Large | 100 | 100 | 100 | 100 | 100 | 100 | 0 |
| | | Small | 100 | 96 | 92 | 100 | 100 | 97.6 | 3.6 |
| | Rear Area | Large | 69 | 64 | 61 | 54 | 57 | 61 | 5.9 |
| | | Small | 19 | 28 | 18 | 22 | 24 | 22.2 | 4.0 |

bombing missions against a forward concentration strategy seems to be lower than the other two strategies in all four plots. By applying the Wilcoxon signed rank test to the data as in MOE #1, it is found that the null hypotheses that the medians of the forward concentration and the balanced defense/rear area concentration for a large/small escort attack on the FEBA/rear area are equal as measured by the percentage of successful bombing missions are rejected for each of the eight cases. Again, the forward concentration emerges as a dominant strategy, as illustrated by the skyscraper plot of MOE #2 in Figure 17 on page 33. When looking at the plot, keep in mind that lower percentages indicate a better strategy.



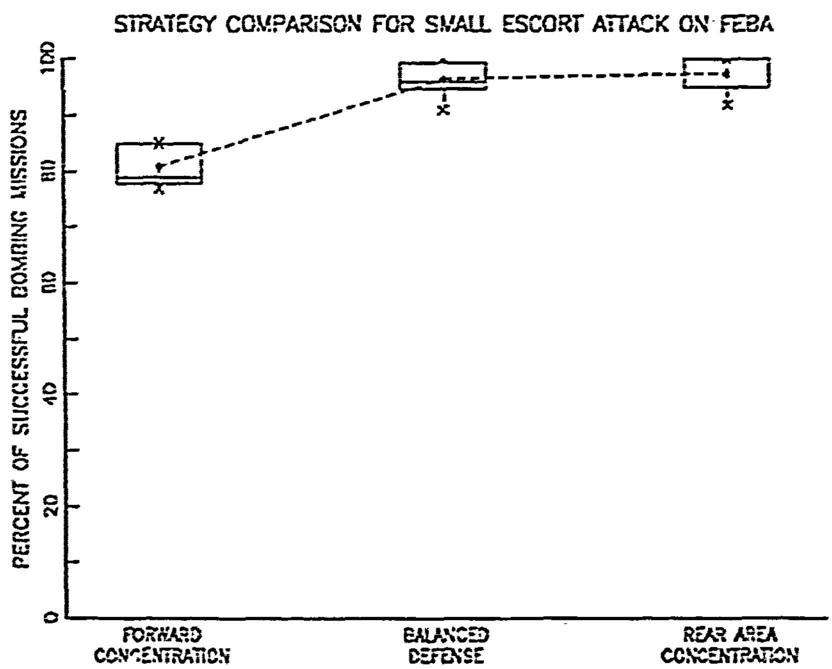




Figure 15. Box Plots Showing MOE #2 Results for Soviet Attack on FEBA

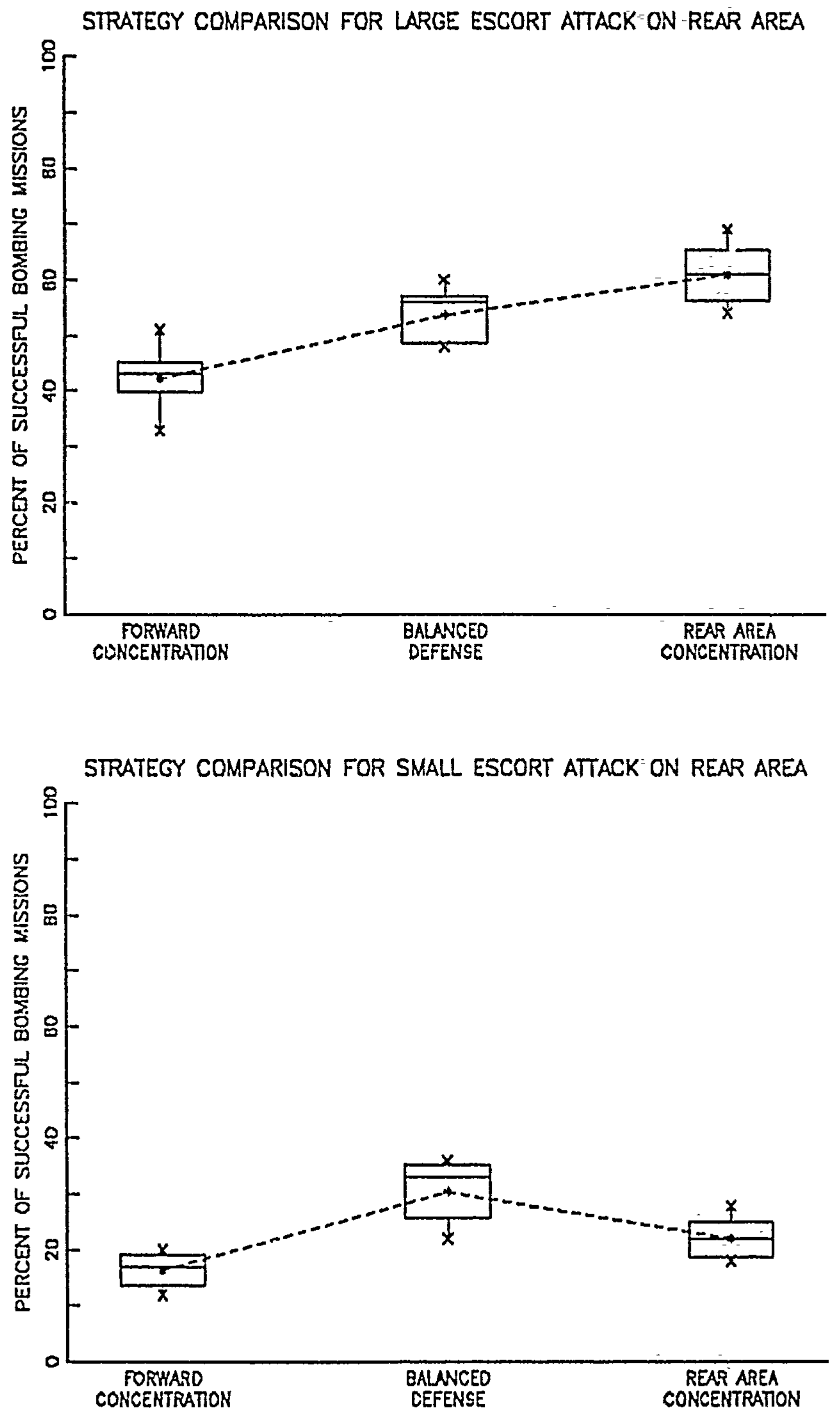



Figure 16. Box Plots Showing MOE #2 Results for Soviet Attack on Rear Area

SKYSCRAPER PLOT OF MOE #2 SAMPLE MEANS

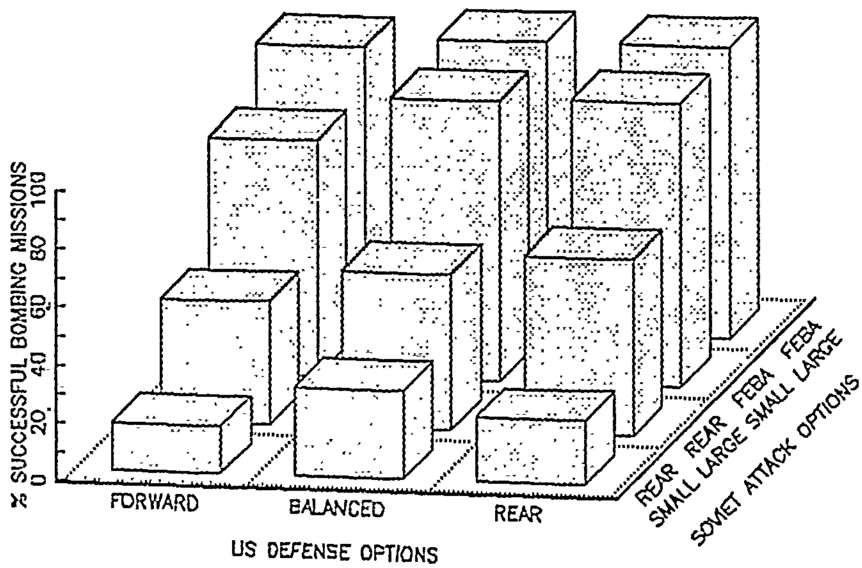



Figure 17. Overall Comparison of Options with MOE #2 Results

## C. MOE #3: NUMBER OF US GROUND-TARGETS DESTROYED

Table 3 shows the simulation results for MOE #3. The box plots for the large and small escort attacks on the rear area in terms of this MOE are presented in Figure 18 on page 35. As explained in Chapter 3, this MOE was only available in the rear area attack scenarios.

Table 3. SIMULATION RESULTS FOR MOE #3: Number of US Targets Destroyed

| Type of ADA Defense | Location of Air Attack | Escort Size | Run #1 | Run #2 | Run #3 | Run #4 | Run #5 | Sample Mean | Sample Std. Dev. |
|---|---|---|---|---|---|---|---|---|---|
| Forward Concentration | Rear Area | Large | 33 | 35 | 31 | 38 | 40 | 35.4 | 3.6 |
| | | Small | 19 | 12 | 5 | 14 | 19 | 13.8 | 5.8 |
| Balanced Defense | Rear Area | Large | 48 | 48 | 52 | 49 | 46 | 48.6 | 2.2 |
| | | Small | 27 | 27 | 26 | 19 | 23 | 24.4 | 3.4 |
| Rear Area Concentration | Rear Area | Large | 56 | 52 | 51 | 34 | 42 | 47 | 8.9 |
| | | Small | 16 | 28 | 15 | 15 | 17 | 18.2 | 5.5 |

One of the suprising results from examining the box plots is that the balanced defense seems to do as well as the rear area concentration when it comes to protecting rear area assets from damage. This could be because the balanced defense attrits some of the planes along the FEBA as they ingress, some of them around the rear area assets, and others along the FEBA as they are on their egress route. Due to the lightly defended FEBA in the rear area concentration strategy, however, the airplanes can adjust their route of attack so as to avoid the air defenses along the FEBA. Consequently, the ADA units are only allowed one chance to attrit the enemy; when they are attacking the rear area targets.

The Wicoxon signed rank test is used to determine if the median number of ground-targets killed in the forward concentration is equal to the medians of the balanced and rear area concentration for large and small escort attacks. The null hypotheses are rejected in all but one case. When comparing the forward concentration to the rear area concentration defense for a small escort attack, the null hypothesis cannot be rejected at the 0.10 significance level. Therefore, in that scenario it is a toss-up as to

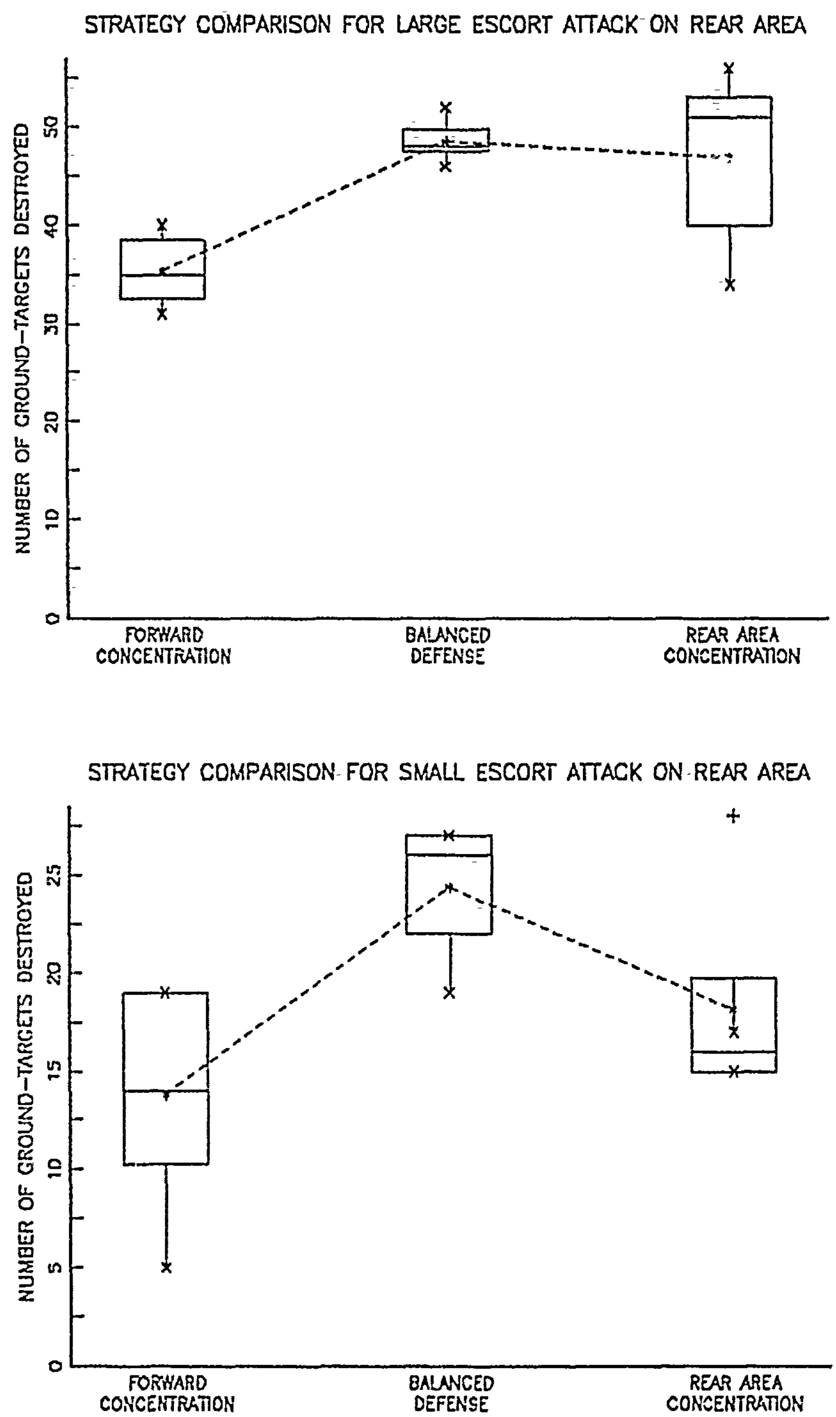



Figure 18. Box Plots Showing MOE #3 Results for Soviet Attack on Rear Area

which defense to employ. From the skyscraper plot (Figure 19 on page 36), it looks as if the height of the 'forward-small' skyscraper is significantly smaller than that of the 'rear-small' skyscraper. This could be true, since the Wilcoxon signed rank test is a test of equality of medians, not means. The box plots in Figure 18 show the sample medians for the two scenarios to be much closer than the sample means.

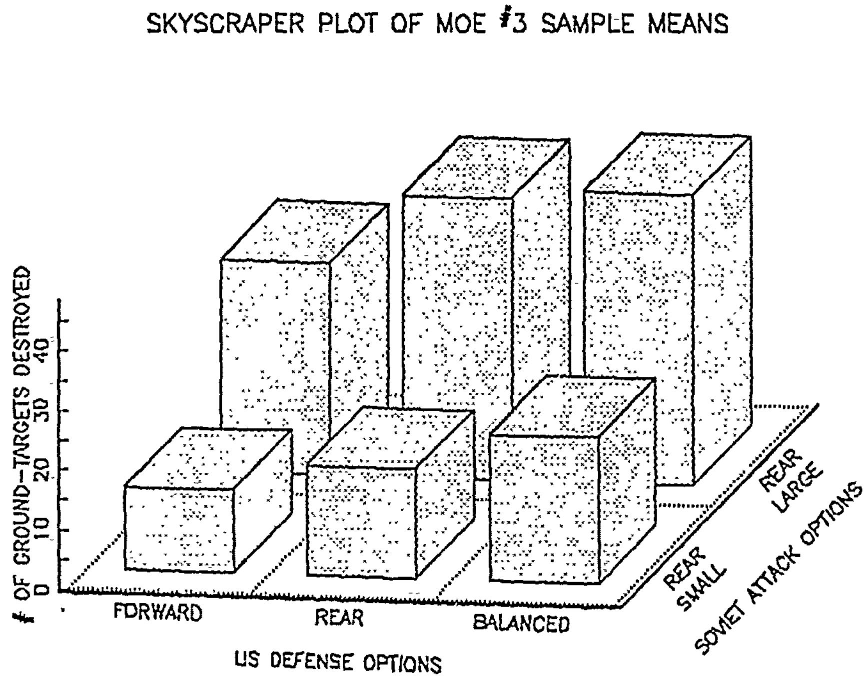



Figure 19. Overall Comparison of Rear Area Attack Options with MOE #3 Results

## D. MODEL EXCURSION

The dominance of the forward concentration defense in all three measures of effectiveness was an unexpected result. How could a forward concentration perform better against a rear area attack than a rear area concentrated defense that was designed specifically for a rear area attack? As argued earlier, to attack a target in the rear area which is defended by a rear area concentration, an airplane can slip through the ADA coverage gaps in the FEBA and then it needs only to survive the heavy coverage around the target. In order to attack the same target defended by a forward concentration, an airplane must survive the trip through the heavy belt of ADA coverage on ingress, a light coverage around the target, and another trip through the forward belt on egress.

In order to further validate the results of the JTLS model and to demonstrate that the 'no gaps and heavy coverage' design of the forward concentration defense strategy is indeed the driving force behind its dominance as measured by the MOEs, two additional scenarios were constructed and run in the JTLS combat model. A new ADA defense 'strategy,' called the reduced forward concentration, was constructed by removing from the model one out of every two adjacent ADA units in the forward concentration defensive belt (see Appendix B for details). This left the forward belt lightly defended by ADA. The reduced forward concentration strategy was tested against two Soviet options: a rear area attack with a large escort size, and a rear area attack with a small escort size. The results are presented in Table 4.

Table 4. SIMULATION RESULTS FOR MODEL EXCURSION: Grouped by MOEs

| MOE #1: Soviet Airplanes Shot Down By US ADA | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Type of ADA Defense | Location of Air Attack | Escort Size | Run #1 | Run #2 | Run #3 | Run #4 | Run #5 | Sample Mean | Sample Std. Dev. |
| Reduced Forward Concentration | Rear Area | Large | 37 | 36 | 39 | 25 | 65 | 40.4 | 14.8 |
| | | Small | 123 | 102 | 138 | 123 | 129 | 123 | 13.2 |

| MOE #2: Percentage of Successful Soviet Bombing Missions | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Type of ADA Defense | Location of Air Attack | Escort Size | Run #1 | Run #2 | Run #3 | Run #4 | Run #5 | Sample Mean | Sample Std. Dev. |
| Reduced Forward Concentration | Rear Area | Large | 76 | 89 | 79 | 90 | 67 | 80.2 | 9.6 |
| | | Small | 47 | 44 | 28 | 32 | 36 | 37.4 | 8.0 |

| MOE #3: Number of US Targets Destroyed | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Type of ADA Defense | Location of Air Attack | Escort Size | Run #1 | Run #2 | Run #3 | Run #4 | Run #5 | Sample Mean | Sample Std. Dev. |
| Reduced Forward Concentration | Rear Area | Large | 61 | 61 | 58 | 61 | 53 | 58.8 | 3.5 |
| | | Small | 36 | 47 | 25 | 27 | 22 | 31.4 | 10.2 |

The reduced forward concentration defense was compared to the rear area concentration defense for analysis. The resulting box plots which illustrate this comparison for each MOE are in Figure 20 on page 39, Figure 21 on page 40, and Figure 22 on page 41. The box plots indicate that rear area concentration performs better than the forward reduced concentration in all cases except possibly for MOE 1 with a small escort size attack. The Wilcoxon signed rank test confirms this indication: the null hypotheses are rejected in favor of the rear area concentration being the better performer in all but the one case described above. This solidifies the theory that the key to the success of the forward concentration defense lies in its heavy concentration of no-gap ADA coverage.

## E. SUMMARY

The data produced by running the twelve scenarios on the JTLS model were analyzed using graphical and nonparametric statistical methods. The results of the analysis show that almost without exception, the forward concentration ADA strategy performed significantly better than the other defenses with respect to every MOE. Also, no defense performed significantly better than the forward concentration defense with respect to any MOE. A model excursion was run that produced results supporting the supposition that the key to the dominance of the forward concentration strategy is its dense coverage without gaps. Normally, a sensitivity analysis would be performed which would result in different strategies being recommended for various scenarios, depending on a subjective weighting of the MOEs. With a dominant strategy, however, no sensitivity analysis is necessary; the forward concentration ADA strategy is the defense of choice for any scenario, independent of the weighting of the MOEs.

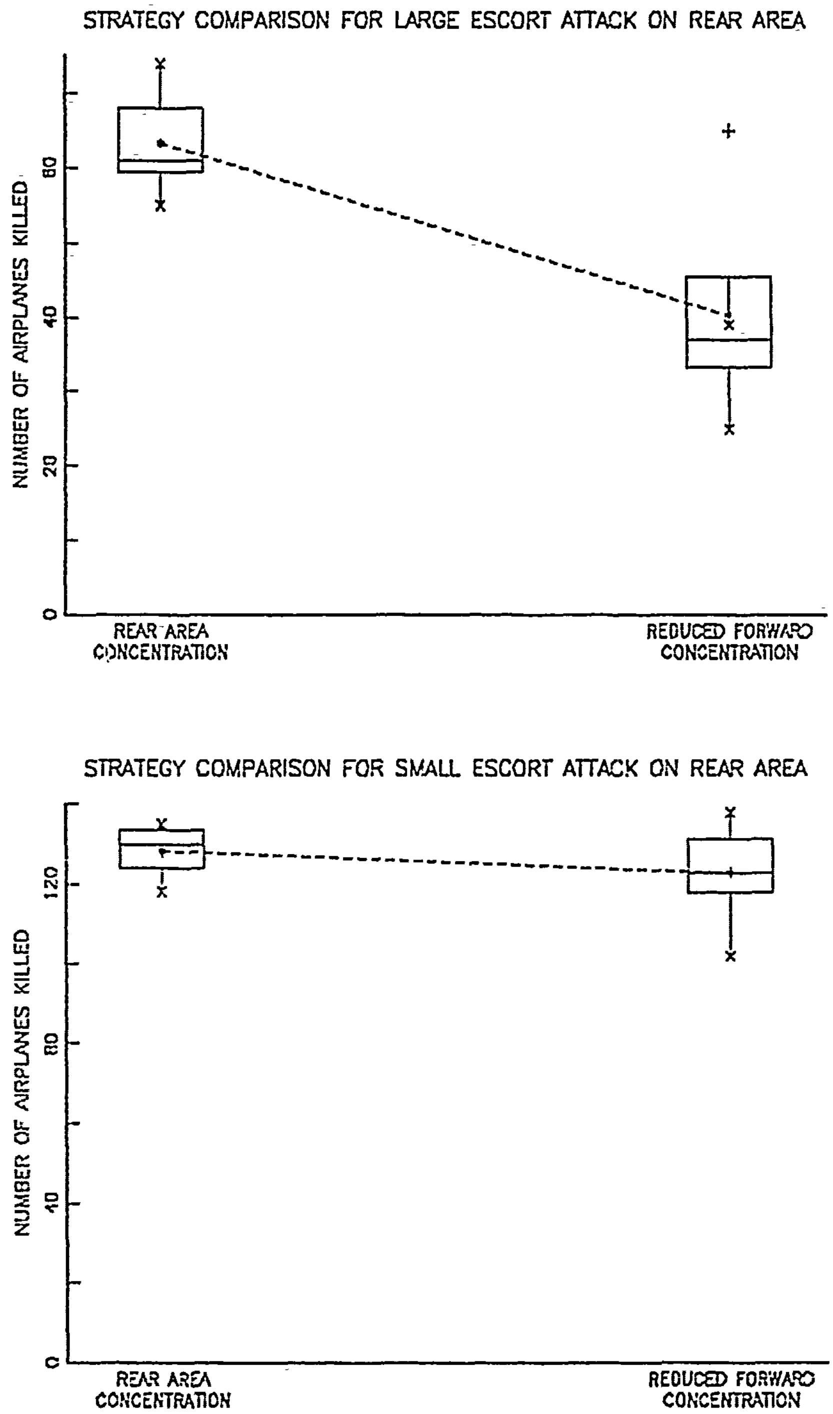
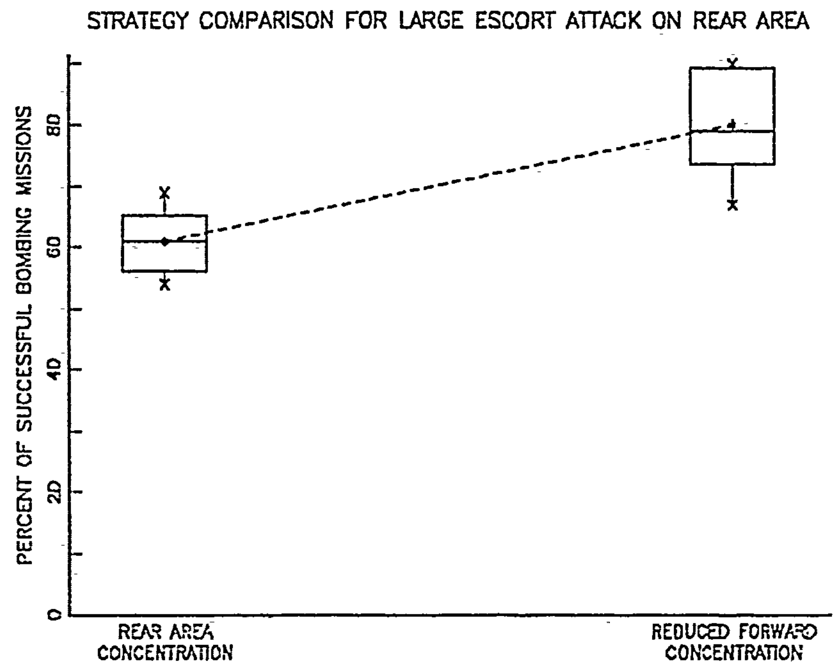



Figure 20. Box Plots Showing Model Excursion Results for MOE #1



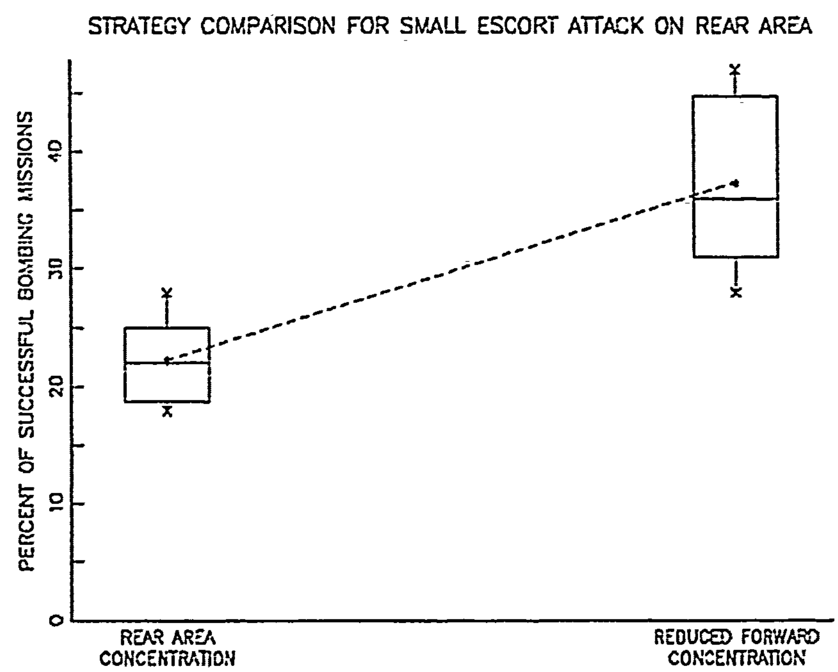
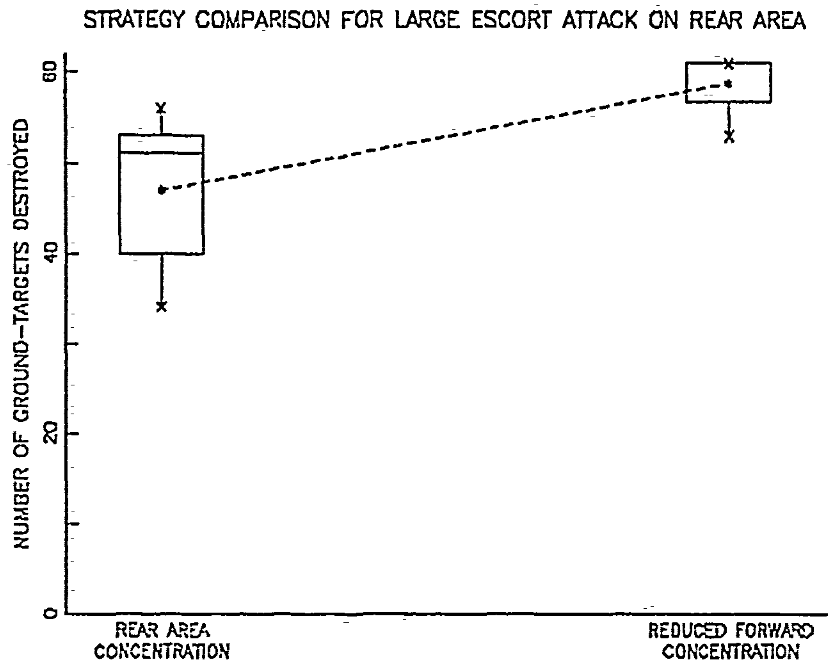




Figure 21. Box Plots Showing Model Excursion Results for MOE #2



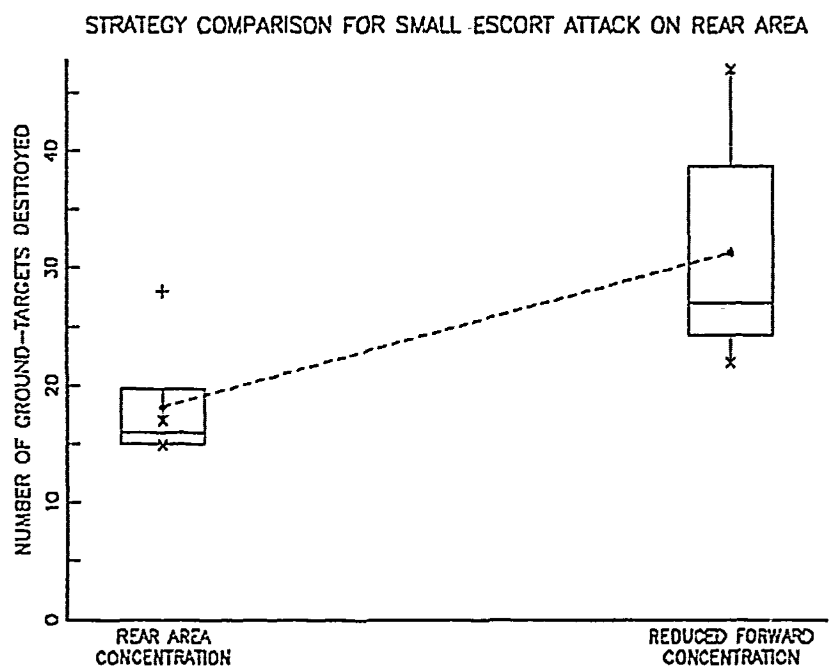




Figure 22. Box Plots Showing Model Excursion Results for MOE #3

# V. CONCLUSIONS AND RECOMMENDATIONS

## A. CONCLUSIONS

The purpose of this thesis was to determine if ADA units positioned in a belt defense performed better than the point defense that the US Army currently uses. It sought to do this through a comparison of three ADA defense strategies:

1. Forward Concentration (belt defense)
2. Balanced Concentration (point defense)
3. Rear Area Concentration (point defense)

The Joint Theater Level Simulation, a computer combat simulation model, was used as a tool for analysis to compare the three strategies in a Fulda Gap scenario against a variety of Soviet attack options. Using the following measures of effectiveness:

1. Soviet airplanes shot down by US ADA,
2. percentage of successful Soviet bombing missions, and
3. number of US ground-targets destroyed,

the forward concentration defense proved to have a significant advantage over the other two strategies, regardless of the weighting of MOEs.

While it is acknowledged that a real-world comparison of these strategies could have different results than this computer simulation, the total dominance of the forward concentration defense strategy is too significant to ignore, even in light of the limitations placed on the scenario as discussed in "3. Scenario Limitations" on page 16. A comparison by computer simulation such as this is just one of the many steps involved in developing new strategies to keep up with changing technologies.

JTLS proved to be a powerful analytical tool in the comparison of ADA strategies. Its potential was barely tapped with the relatively small simulation used in this thesis. With a large, analytical study run by a dozen or more people, the ample analytical capabilities of JTLS could be exercised. The planned improvements such as revision of the postprocessor function and availability of detailed logistical information serve to increase its attractiveness as an analytical tool.

## B. RECOMMENDATIONS

The results of this thesis are significant enough to warrant further study into the comparative effectiveness of the forward concentration defense strategy. Immediate follow-on research should focus on expansion of scenarios to exploit JTLS capabilities. If the results are still significant, future research should use different models, and eventually field exercises to validate results already obtained. Specific reccommendations for immediate follow-on research are:

1. Repeat the strategy comparison using a classified database. Although the database used for this thesis contained highly reasonable figures, they were not the actual classified values.
2. Increase the number of runs in a cell to 20 or more, and attempt to fit the data to a distribution. This would aid the process of statistical analysis.
3. Incorporate US Air Force and logistics into the analysis. Although this will greatly complicate the scenario programming and data analysis efforts, both of these areas are needed in the model before it can be considered to have real-world application.
4. Extend the war from one day to one week. This will show the effects of attrition over a period of time on the different strategies. If logistics is played, any effects of logistical shortfalls will surface.

Finally, this thesis has demonstrated that JTLS is, indeed, suitable for evaluating tactics and doctrine in a variety of scenarios. In particular, use of the model to investigate various tactics in an environment such as Desert Shield could provide valuable insights to military planners.

# APPENDIX A. UNIT LOCATIONS AT BEGINNING OF SCENARIO

The following two lists contain the JTLS short name and beginning location for the units (except ADA units) involved in the combat model simulation.

## A. US FORCES

| UNIT NAME | LATITUDE | LONGITUDE |
|---|---|---|
| CENTAG | 49-25-58N | 7-39-54E |
| 21SUPCOM | 49-27-28N | 7-50-31E |
| 212.HVY | 49-27-28N | 7-50-31E |
| VCORPS | 50-04-49N | 8-41-59E |
| V.COSCOM | 50-31-00N | 8-41-59E |
| HQ/4AD | 50-49-58N | 9-28-59E |
| 1/4AD | 50-48-00N | 9-49-58E |
| 2/4AD | 50-56-59N | 9-51-00E |
| 3/4AD | 50-53-59N | 9-45-00E |
| 4/43FA | 50-50-59N | 9-43-58E |
| HQ/5AD | 50-12-00N | 8-26-59E |
| 1/5AD | 50-12-00N | 8-26-59E |
| 2/5AD | 50-12-00N | 8-26-59E |
| 3/5AD | 50-12-00N | 8-26-59E |
| 5/43FA | 50-12-00N | 8-26-59E |
| HQ/8ID | 50-34-58N | 9-23-59E |
| 1/8ID | 50-25-01N | 9-52-59E |
| 2/8ID | 50-28-01N | 9-43-00E |
| 3/8ID | 50-37-01N | 9-43-00E |
| 4/562FA | 50-34-00N | 9-37-00E |
| HQ/9ID | 50-19-59N | 9-18-00E |
| 1/9ID | 50-19-59N | 9-18-00E |
| 2/9ID | 50-19-59N | 9-18-00E |
| 3/9ID | 50-19-59N | 9-18-00E |
| 5/562FA | 50-19-59N | 9-18-00E |
| HQ/2AD | 50-46-00N | 9-13-00E |
| 1/2AD | 50-43-59N | 9-40-01E |
| 2/2AD | 50-48-44N | 9-28-39E |
| 3/2AD | 50-43-00N | 9-18-00E |
| 2/43FA | 50-40-01N | 9-36-00E |
| FRANKFURT | 50-00-57N | 8-32-29E |
| 353/A10 | 50-00-57N | 8-32-29E |
| 355/A10 | 50-00-57N | 8-32-29E |
| 71/F4 | 50-00-57N | 8-32-29E |
| 567/F4 | 50-00-57N | 8-32-29E |
| RAMSTEIN | 49-27-18N | 7-32-02E |
| 165TFW.F1 | 49-27-18N | 7-32-02E |
| 552/1 E3A | 49-27-18N | 7-32-02E |
| 352 TKR | 49-27-18N | 7-32-02E |
| 17 RF4 | 49-27-18N | 7-32-02E |
| 2.FARP | 50-25-58N | 8-52-59E |
| 1ATK.HELO | 50-25-58N | 8-52-59E |
| 2ATK.HELO | 50-25-58N | 8-52-59E |
| BITBURG | 50-23-59N | 7-33-00E |

| UNIT NAME | LATITUDE | LONGITUDE |
|---|---|---|
| 1TFS/A10 | 50-23-59N | 7-33-00E |
| 99TFS A10 | 50-23-59N | 7-33-00E |
| 28TFS/F15 | 50-23-59N | 7-33-00E |
| 27TFS/F15 | 50-23-59N | 7-33-00E |
| HQ/62AD | 49-27-18N | 7-32-02E |
| 1/62AD | 49-27-18N | 7-32-02E |
| 2/62AD | 49-27-18N | 7-32-02E |
| 3/62AD | 49-27-18N | 7-32-02E |
| HQ/62AD | 49-27-18N | 7-32-02E |

B. SOVIET FORCES

| UNIT NAME | LATITUDE | LONGITUDE |
|---|---|---|
| GSFD | 51-25-29N | 12-01-37E |
| 12FSB | 51-18-46N | 12-04-29E |
| 12AMB | 51-10-17N | 11-45-00E |
| 10TD | 51-00-59N | 10-57-57E |
| 1 10TD | 51-03-57N | 10-41-59E |
| 2 10TD | 50-56-59N | 10-42-57E |
| 3 10TD | 50-50-59N | 10-55-58E |
| 2CAA | 51-05-59N | 11-03-00E |
| 14MRD | 50-37-00N | 10-09-59E |
| 1 14MRR | 50-40-01N | 10-19-00E |
| 2 14MRR | 50-32-59N | 10-19-00E |
| 3 14MRR | 50-37-00N | 10-09-59E |
| 14TR | 50-45-00N | 10-30-00E |
| 12MRD | 51-00-00N | 10-23-59E |
| 1 12MRR | 50-57-57N | 10-11-59E |
| 2 12MRR | 50-47-59N | 10-09-57E |
| 3 12MRR | 50-42-00N | 10-07-58E |
| 12TR | 50-51-57N | 10-18-00E |
| DAG.14 | 50-34-58N | 10-26-59E |
| DAG.12 | 50-49-00N | 10-19-00E |
| 22TAA | 51-43-58N | 11-56-59E |
| 7.FTR BMR | 51-43-58N | 11-56-59E |
| 8.FTR | 51-43-58N | 11-56-59E |
| 9.FTR BMR | 51-43-58N | 11-56-59E |
| 10.BMR | 51-43-58N | 11-56-59E |
| 57 LIFT | 51-43-58N | 11-56-59E |
| WEIMARAFB | 50-58-29N | 11-19-58E |
| 1.FTR.AD | 50-58-29N | 11-19-58E |
| 2.FTR.AD | 50-58-29N | 11-19-58E |
| LEIPZIG | 51-24-00N | 12-26-59E |
| 5.FTR BMR | 51-24-00N | 12-26-59E |
| 6.BMR | 51-24-00N | 12-26-59E |
| DAG.24 | 50-43-00N | 11-15-00E |

## APPENDIX B. LOCATIONS OF ADA UNITS

The following four lists contain the JTLS short name and location of the ADA units in each of the three ADA defense strategies, plus the excursion scenario.

### A. BALANCED DEFENSE

| UNIT NAME | LATITUDE | LONGITUDE |
|---|---|---|
| 101SAM-HWK01 | 50-33N | 7-36E |
| 107SAM-HWK07 | 50-24N | 7-50E |
| 110SAM-HWK10 | 50-24N | 7-50E |
| 21SUPCOM-HM | 49-33N | 7-47E |
| 21SUPCOM-MM | 49-27N | 7-52E |
| FRANKFUR-HM | 50-09N | 8-44E |
| FRANKFUR-MM | 50-02N | 8-51E |
| HQ/2AD-HM | 50-46N | 9-13E |
| HQ/2AD-MM | 50-46N | 9-13E |
| HQ/4AD-HM | 50-50N | 9-29E |
| HQ/4AD-MM | 50-50N | 9-29E |
| HQ/5AD-HM | 50-12N | 8-27E |
| HQ/5AD-MM | 50-12N | 8-27E |
| HQ/8ID-HM | 50-35N | 9-24E |
| HQ/8ID-MM | 50-35N | 9-24E |
| HQ/9ID-HM | 50-20N | 9-18E |
| HQ/9ID-MM | 50-20N | 9-18E |
| RAMSTEIN-HM | 49-37N | 7-38E |
| RAMSTEIN-MM | 49-37N | 7-28E |
| 0005SAM-JAWS | 50-30N | 7-44E |
| V.COSCOM-HM | 50-17N | 8-37E |
| V.COSCOM-MM | 50-13N | 8-52E |

### B. FORWARD CONCENTRATION DEFENSE

| UNIT NAME | LATITUDE | LONGITUDE |
|---|---|---|
| 101SAM-HWK01 | 51-00N | 9-35E |
| 107SAM-HWK07 | 50-52N | 9-35E |
| 110SAM-HWK10 | 50-46N | 9-33E |
| 21SUPCOM-HM | 50-55N | 9-36E |
| 21SUPCOM-MM | 50-39N | 9-31E |
| FRANKFUR-HM | 50-09N | 8-44E |
| FRANKFUR-MM | 50-33N | 9-31E |
| HQ/2AD-HM | 50-46N | 9-13E |
| HQ/2AD-MM | 50-46N | 9-13E |
| HQ/4AD-HM | 50-50N | 9-29E |
| HQ/4AD-MM | 50-50N | 9-29E |
| HQ/5AD-HM | 50-42N | 9-33E |
| HQ/5AD-MM | 50-38N | 9-15E |
| HQ/8ID-HM | 50-35N | 9-24E |

| UNIT NAME | LATITUDE | LONGITUDE |
|---|---|---|
| HQ 8ID-MM | 50-35N | 9-24E |
| HQ 9ID-HM | 50-27N | 9-40E |
| HQ 9ID-MM | 50-24N | 9-46E |
| RAMSTEIN-HM | 49-37N | 7-28E |
| RAMSTEIN-MM | 50-20N | 9-54E |
| 0005SAM-JAWS | 50-30N | 7-44E |
| V.COSCOM-HM | 50-12N | 8-41E |
| V.COSCOM-MM | 50-31N | 9-23E |

## C. REAR AREA CONCENTRATION DEFENSE

| UNIT NAME | LATITUDE | LONGITUDE |
|---|---|---|
| 101SAM-HWK01 | 50-33N | 7-36E |
| 107SAM-HWK07 | 50-24N | 7-50E |
| 110SAM-HWK10 | 50-24N | 7-50E |
| 21SUPCOM-HM | 49-33N | 7-47E |
| 21SUPCOM-MM | 49-27N | 7-52E |
| FRANKFUR-HM | 50-09N | 8-44E |
| FRANKFUR-MM | 50-02N | 8-51E |
| HQ 2AD-HM | 50-28N | 7-48E |
| HQ 2AD-MM | 50-46N | 9-13E |
| HQ 4AD-HM | 50-21N | 7-28E |
| HQ 4AD-MM | 50-50N | 9-29E |
| HQ 5AD-HM | 50-10N | 8-37E |
| HQ 5AD-MM | 50-12N | 8-27E |
| HQ 8ID-HM | 49-24N | 7-25E |
| HQ 8ID-MM | 50-35N | 9-24E |
| HQ 9ID-HM | 50-20N | 9-18E |
| HQ 9ID-MM | 49-36N | 7-47E |
| RAMSTEIN-HM | 49-37N | 7-38E |
| RAMSTEIN-MM | 49-37N | 7-28E |
| 0005SAM-JAWS | 50-30N | 7-44E |
| V.COSCOM-HM | 50-17N | 8-37E |
| V.COSCOM-MM | 50-13N | 8-52E |

## D. REDUCED FORWARD CONCENTRATION DEFENSE

| UNIT NAME | LATITUDE | LONGITUDE |
|---|---|---|
| 107SAM-HWK07 | 50-52N | 9-35E |
| 21SUPCOM-MM | 50-39N | 9-31E |
| FRANKFUR-HM | 50-09N | 8-44E |
| HQ 2AD-HM | 50-46N | 9-13E |
| HQ 2AD-MM | 50-46N | 9-13E |
| HQ 4AD-HM | 50-50N | 9-29E |
| HQ 4AD-MM | 50-50N | 9-29E |
| HQ 8ID-HM | 50-35N | 9-24E |
| HQ 8ID-MM | 50-35N | 9-24E |
| HQ 9ID-HM | 50-27N | 9-40E |
| RAMSTEIN-HM | 49-37N | 7-28E |
| RAMSTEIN-MM | 50-20N | 9-54E |
| 0005SAM-JAWS | 50-30N | 7-44E |
| V.COSCOM-HM | 50-12N | 8-41E |

## APPENDIX C. DESCRIPTION OF SOVIET AIR MISSIONS

The following two lists contain the composition, attack time, and targets for each of the air attack missions. The terms in parentheses are the NATO names for the airplanes used.

### A. MAXIMUM ESCORT MISSIONS

MISSION NAME:

| | | |
|---|---|---|
| MAX1 | COMPOSITION: | 15 Bombers (FITTER)<br>2 Jammers (BACKFIRE)<br>8 Wild Weasels (FLOGGERS)<br>5 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 0700 hrs. |
| | TARGETS, FEBA: | 2/4AD, HQ/4AD |
| | TARGETS, Rear: | Bitburg, Frankfurt |
| MAX2 | COMPOSITION: | 6 Bombers (BACKFIRE)<br>6 Bombers (FITTER)<br>2 Jammers (BACKFIRE)<br>8 Wild Weasels (FLOGGERS)<br>5 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 0730 hrs. |
| | TARGETS, FEBA: | 1/4AD, 1/2AD |
| | TARGETS, Rear: | Frankfurt, Ramstein |
| MAX3 | COMPOSITION: | 15 Bombers (FITTER)<br>2 Jammers (BACKFIRE)<br>8 Wild Weasels (FLOGGERS)<br>5 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 0800 hrs. |
| | TARGETS, FEBA: | 2/8ID, HQ/8ID |
| | TARGETS, Rear: | Ramstein, Bitburg |
| MAX4 | COMPOSITION: | 15 Bombers (FITTER)<br>2 Jammers (BACKFIRE)<br>8 Wild Weasels (FLOGGERS)<br>5 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1300 hrs. |
| | TARGETS, FEBA: | 3/4AD, 2/4AD |
| | TARGETS, Rear: | Bitburg, Frankfurt |

MAX5

COMPOSITION:
6 Bombers (BACKFIRE)
6 Bombers (FITTER)
2 Jammers (BACKFIRE)
8 Wild Weasels (FLOGGERS)
5 Air-to-Air (FLOGGERS)

ATTACK TIME: 1330 hrs.
TARGETS, FEBA: 2/4AD, 3/4AD
TARGETS, Rear: Frankfurt, Ramstein

MAX6

COMPOSITION:
15 Bombers (FITTER)
2 Jammers (BACKFIRE)
8 Wild Weasels (FLOGGERS)
5 Air-to-Air (FLOGGERS)

ATTACK TIME: 1400 hrs.
TARGETS, FEBA: 3/8ID, HQ/8ID
TARGETS, Rear: Ramstein, Frankfurt

## B. MINIMUM ESCORT MISSIONS

MISSION NAME:

MIN1

COMPOSITION:
4 Bombers (FITTER)
1 Jammer (BACKFIRE)
2 Wild Weasels (FLOGGERS)
2 Air-to-Air (FLOGGERS)

ATTACK TIME: 0700 hrs.
TARGETS, FEBA: 2/4AD, 3/4AD
TARGETS, Rear: Bitburg, Frankfurt

MIN2

COMPOSITION: 3 Bombers (BACKFIRE)
1 Bomber (FITTER)
1 Jammer (BACKFIRE)
2 Wild Weasels (FLOGGERS)
3 Air-to-Air (FLOGGERS)

ATTACK TIME: 0705 hrs.
TARGETS, FEBA: 2/2AD, HQ/4AD
TARGETS, Rear: Bitburg, Ramstein

MIN3

COMPOSITION:
4 Bombers (FITTER)
1 Jammer (BACKFIRE)
2 Wild Weasels (FLOGGERS)
2 Air-to-Air (FLOGGERS)

ATTACK TIME: 0710 hrs.
TARGETS, FEBA: 2/4AD, 3/4AD
TARGETS, Rear: Bitburg, Frankfurt

MIN4

COMPOSITION:
4 Bombers (FITTER)
1 Jammer (BACKFIRE)
2 Wild Weasels (FLOGGERS)
2 Air-to-Air (FLOGGERS)

ATTACK TIME: 0710 hrs.
TARGETS, FEBA: 1/2AD, 2/43FA
TARGETS, Rear: Frankfurt, Ramstein

| | | |
|---|---|---|
| MIN5 | COMPOSITION: | 4 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>3 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 0800 hrs. |
| | TARGETS, FEBA: | 2/43FA, 3/8ID |
| | TARGETS, Rear: | Frankfurt, Bitburg |
| MIN6 | COMPOSITION: | 4 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>2 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 0830 hrs. |
| | TARGETS, FEBA: | 3/8ID, 2/43FA |
| | TARGETS, Rear: | Frankfurt, Ramstein |
| MIN7 | COMPOSITION: | 5 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>2 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 0900 hrs. |
| | TARGETS, FEBA: | 2/8ID, HQ/8ID |
| | TARGETS, Rear: | Ramstein, Bitburg |
| MIN8 | COMPOSITION: | 5 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>3 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 0930 hrs. |
| | TARGETS, FEBA: | 2/8ID, HQ/8ID |
| | TARGETS, Rear: | Ramstein, Frankfurt |
| MIN9 | COMPOSITION: | 5 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>2 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1000 hrs. |
| | TARGETS, FEBA: | 4/562FA, 2/8ID |
| | TARGETS, Rear: | Ramstein, Bitburg |
| MIN10 | COMPOSITION: | 4 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>2 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1030 hrs. |
| | TARGETS, FEBA: | 1/4AD, 4/43FA |
| | TARGETS, Rear: | Bitburg, Frankfurt |

| | | |
|---|---|---|
| MIN11 | COMPOSITION: | 3 Bombers (BACKFIRE)<br>1 Bomber (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>3 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1100 hrs. |
| | TARGETS, FEBA: | 3/4AD, 1/2AD |
| | TARGETS, Rear: | Bitburg, Ramstein |
| MIN12 | COMPOSITION: | 4 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>2 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1130 hrs. |
| | TARGETS, FEBA: | 2/4AD, 4/43FA |
| | TARGETS, Rear: | Bitburg, Frankfurt |
| MIN13 | COMPOSITION: | 5 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>2 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1200 hrs. |
| | TARGETS, FEBA: | 1/2AD, HQ/4AD |
| | TARGETS, Rear: | Frankfurt, Ramstein |
| MIN14 | COMPOSITION: | 5 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>3 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1230 hrs. |
| | TARGETS, FEBA: | 2/43FA, HQ/8ID |
| | TARGETS, Rear: | Frankfurt, Bitburg |
| MIN15 | COMPOSITION: | 5 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>2 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1300 hrs. |
| | TARGETS, FEBA: | HQ/8ID, 2/43FA |
| | TARGETS, Rear: | Frankfurt, Ramstein |
| MIN16 | COMPOSITION: | 4 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>2 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1330 hrs. |
| | TARGETS, FEBA: | 4/562FA, HQ/8ID |
| | TARGETS, Rear: | Ramstein, Bitburg |

| | | |
|---|---|---|
| MIN17 | COMPOSITION: | 4 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>3 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1400 hrs. |
| | TARGETS, FEBA: | 4/43FA, HQ/4AD |
| | TARGETS, Rear: | Ramstein, Frankfurt |
| MIN18 | COMPOSITION: | 4 Bombers (FITTER)<br>1 Jammer (BACKFIRE)<br>2 Wild Weasels (FLOGGERS)<br>2 Air-to-Air (FLOGGERS) |
| | ATTACK TIME: | 1430 hrs. |
| | TARGETS, FEBA: | HQ/2AD, 3/2AD |
| | TARGETS, Rear: | Ramstein, Bitburg |

# APPENDIX D. EXPLANATION OF BOX PLOTS

The symbols used in the box plots contained in this thesis and their corresponding meanings are as follows:

- The top and bottom of the rectangle, or box, represent the upper and lower quartiles of the data.
- The sample median is portrayed by a horizontal line segment within the rectangle.
- Solid lines extend from the top and bottom of the box to adjacent values, denoted by 'x'. The upper adjacent value is the largest observatio.. that is less than or equal to the upper quartile plus (1.5 x interquartile range). Conversely, the lower adjacent value is the smallest observation that is greater than or equal to the lower quartile minus (1.5 x interquartile range).
- Any observation that falls outside the range of the two adjacent values is called an outside value, and is plotted individually as a '+'.
- Dashed lines are used to connect the sample mean, denoted by '*', of one sample to another. [Ref. 8: p. 21]

# APPENDIX E. WILCOXON SIGNED RANK TEST RESULTS

This appendix contains details of the Wilcoxon signed rank test procedures as they are applied to the hypothesis testing in Chapter IV. In each case, the null hypothesis is that the sample medians are the same. The symbol '>' in the alternate hypothesis is used to indicate that the median of the first scenario is greater than the median of the second. The short names used to indicate scenarios are:

- FC = forward concentration
- BA = balanced
- RC = rear area concentration
- RF = reduced forward concentration
- LG = large escort
- SM = small escort
- FB = FEBA attack
- RA = rear area attack

The numbers in the signed rank column are the magnitudes (in ranked order with sign attached) of the differences in the observations from each run of the corresponding scenarios. The Wilcoxon signed rank test statistic ($T_-$) is the sum of the ranks with negative signs. The midrank method is used to assign ranks for ties. For a sample size of five and an $\alpha = 0.10$, the null hypothesis is rejected when $T_- < 3$. For a sample size of four (used in one case because of a zero value data point), the critical value is 1.

## A. MOE #1

| ALTERNATE HYPOTHESIS | SIGNED RANK | T_ | NULL HYPOTHESIS REJECTED? |
|---|---|---|---|
| FB-LG-FC > FB-LG-BA | 4 6 7 7 15 | 0 | YES |
| FB-LG-FC > FB-LG-RC | 6 8 8 9 16 | 0 | YES |
| FB-SM-FC > FB-SM-BA | 35 42 44 45 47 | 0 | YES |
| FB-SM-FC > FB-SM-RC | 37 45 46 46 51 | 0 | YES |
| RA-LG-FC > RA-LG-BA | 21 29 35 38 60 | 0 | YES |
| RA-LG-FC > RA-LG-RC | 31 35 38 47 64 | 0 | YES |
| RA-SM-FC > RA-SM-BA | 14 15 17 27 34 | 0 | YES |
| RA-SM-FC > RA-SM-RC | 17 18 18 22 34 | 0 | YES |
| RA-LG-RC > RA-LG-RF | 9 19 22 24 41 | 0 | YES |
| RA-SM-RC > RA-SM-RF | 1 3 -3 10 16 | 2.5 | YES |

B. MOE #2

| ALTERNATE HYPOTHESIS | SIGNED RANK | T_ | NULL HYPOTHESIS REJECTED? |
|---|---|---|---|
| FB-LG-FC > FB-LG-BA | 1 1 4 4 8 | 0 | YES |
| FB-LG-FC > FB-LG-RC | 1 1 4 5 8 | 0 | YES |
| FB-SM-FC > FB-SM-BA | 11 12 14 19 22 | 0 | YES |
| FB-SM-FC > FB-SM-RC | 13 15 15 19 22 | 0 | YES |
| RA-LG-FC > RA-LG-BA | -2 5 13 14 27 | 1 | YES |
| RA-LG-FC > RA-LG-RC | 11 13 15 26 28 | 0 | YES |
| RA-SM-FC > RA-SM-BA | 8 14 15 16 18 | 0 | YES |
| RA-SM-FC > RA-SM-RC | 0 4 6 8 11 | 0 | YES |
| RA-LG-RC > RA-LG-RF | 7 10 18 25 36 | 0 | YES |
| RA-SM-RC > RA-SM-RF | 10 10 12 16 28 | 0 | YES |

C. MOE #3

| ALTERNATE HYPOTHESIS | SIGNED RANK | T_ | NULL HYPOTHESIS REJECTED? |
|---|---|---|---|
| RA-LG-FC > RA-LG-BA | 6 11 13 15 21 | 0 | YES |
| RA-LG-FC > RA-LG-RC | 2 -4 17 20 23 | 2 | YES |
| RA-SM-FC > RA-SM-BA | 4 5 8 15 21 | 0 | YES |
| RA-SM-FC > RA-SM-RC | 1 -2 -3 10 16 | 5 | NO |
| RA-LG-RC > RA-LG-RF | 5 7 9 11 27 | 0 | YES |
| RA-SM-RC > RA-SM-RF | 5 10 12 19 20 | 0 | YES |

# LIST OF REFERENCES


1.
United States Army,
*Field Manual 44-1, US Army Air Defense Artillery Employment,*
Headquarters, Department of the Army, May 1983.

2.
United States Army,
*Field Manual 100-5, OPERATIONS,*
Headquarters, Department of the Army, May 1986.

3.
Gabriel, Richard A.,
*NATO and the Warsaw Pact,*
Greenwood Press, 1983.

4.
Force Structure, Resource, and assessment Directorate (J-8), Joint Chiefs of Staff, *JTLS Player Guide,* The Pentagon, May 1990.

5.
Interview between Edward P. Kelleher, Analyst, Rolands and Associates Corporation, and the author, 1 September, 1990.

6.
Force Structure, Resource, and assessment Directorate (J-8), Joint Chiefs of Staff, *JTLS Executive Overview,* The Pentagon, May 1990.

7.
Gibbons, Jean Dickinson,
*Nonparametric Methods for Quantitative Analysis (Second Edition),*
Columbus, OH, 1985.

8.
Chambers, J.M., and others,
*Graphical Methods for Data Analysis,*
Duxbury Press, 1983.

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